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SOME NOTES ON UNDERGROUND TRANSPORTATION

BY

C. F. JACKSON

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September, 1930.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

SOME NOTES ON UNDERGROUND TRANSPORTATION IN METAL MINES[1]

By C. F. Jackson[2]

INTRODUCTION

This paper has been prepared as a progress report in connection with the series of articles on mining methods and costs which are being published by the U. S. Bureau of Mines in the form of information circulars. When enough circulars have been completed it is planned to publish a more complete and comprehensive paper in bulletin form dealing with the subject of underground transportation.

Progress reports, followed by bulletins, will be prepared from time to time dealing with other subjects included in the general study of mining methods at individual mines, such as mine development, drilling, and blasting; stoping methods (each principal stoping method to be summarized in a separate paper); ventilation; wage, contract and bonus systems, etc.

The term "transportation" has been used in the title of this paper to include the handling and movement of ore from the time it leaves the stope until its arrival on surface. Incidentally, it includes the handling of materials, tools, and supplies and of waste rock. Transportation as here used, thus embraces the operations more commonly known as tramming, haulage, dumping, caging, and hoisting. Where ore is drawn from chutes, "transportation" also includes the operation of loading the cars.

Importance and Cost of Underground Transportation

The cost of underground transportation as above defined is a very appreciable percentage of the total mining cost in most mines; in some mines, in fact, it accounts for a larger percentage than the stoping cost, and in one mine studied, over 56 per cent of the total underground cost was attributable to transportation. For 15 mines using open-stope methods of mining, transportation costs amounted to 28.4 per cent of the total underground cost[3], for 19 mines employing

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6326."

2 Senior mining engineer, U. S. Bureau of Mines.

3 Jackson, Chas. F., Mining Ore in Open Stopes, Eastern and Central United States. Information Circular 6193, Bureau of Mines, 1929, 30 pp.

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shrinkage stoping, to 22.65 per cent;[4] for 4 mines using cut and fill as the principal method of stoping, to 12.9 per cent; for 5 mines using square-setting as the principal method, to 13.83 per cent; and for 3 mines using the block-caving system, to 21.3 per cent. For those groups showing the lowest percentages of total cost for transportation the actual dollar cost per ton was higher than for some of those showing the higher percentage of total cost, the reason for the lower percentage figures being that other costs and the total costs were more than proportionately higher. Average transportation costs and percentages of total underground costs are tabulated below: These are direct operating costs only and do not include depreciation and overhead costs.

Average transportation costs and percentages of total underground costs

Mining method	Cost of underground transportation per ton of ore hoisted	Total underground cost	Underground transportation, per cent of total cost
Open stopes:			
Average of 15 mines..	$0.303	$1.067	28.40
Shrinkage stoping:			
Average of 7 mines...	.516	2.555	20.20
Average of 19 mines..	(Reports give percentages only)		22.65
Block caving:			
Average of 3 mines...	.1135	.535	21.03
Square-set stoping:			
Average of 5 mines...	.612	4.419	13.83
Cut-and-fill stoping:			
Average of 4 mines...	.4025	3.120	12.90

The labor costs for transportation underground at a number of mines expressed in man-hours per ton of ore hoisted, and the total underground man-hours per ton for the same mines are tabulated below:

4 Jackson, Chas. F., Shrinkage Stoping. Information Circular 6293, Bureau of Mines, June, 1930.

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Transportation costs in man-hours per ton

Mining method	Man-hours per ton for underground transportation	Total underground man-hours per ton	Transportation man-hours per ton, per cent of total man-hours per ton
Open stopes: Average for 15 mines..	0.275	.983	27.98
Shrinkage stoping: Average of 14 mines...	0.610	2.516	24.2
Square-set-stoping: Average of 3 mines....	0.433	3.973	10.80
Cut-and-fill: Average of 4 mines....	0.467	3.247	14.38

These figures in the first and third columns of the above tables are probably low, rather than the reverse, since considerable tramming is usually done in connection with shoveling and is carried on the cost sheet under shoveling. Additional data are given in Table 6 appended hereto.

HAULAGE

Underground haulage is of three principal types: hand-tramming, animal haulage, and mechanical haulage. Some mines only employ one of these types, whereas others may use combinations of two or of all three types.

Hand-Tramming

Hand-tramming as the principal method of haulage is to-day largely confined to small mines having a small output. The word "small" as applied to mines is only a relative term and capable of various interpretations. As compared to a mine producing 5,000 tons per day, one producing 1,000 tons would be a small mine, but the latter would be considered a large mine as compared to one with a daily output of 250 tons. A mine may be small in point of output but large as regards area of workings and mileage of drifts and crosscuts.

The designation "small mine" is here applied to mines having outputs of 300 or 400 tons per day or less. This would seem to be the justifiable upper limit in this country to-day for the use of hand-tramming as the principal method except where the tramming distance is very short, haulageways very crooked, or the production is so widely scattered that only a very small tonnage comes from each point of production. With the small storage-battery locomotives of the so-called tramming type which can be run on a cage and transferred quickly from level to level and which have been on the market for several years, the economical limits for hand-tramming are below those formerly existing.

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The determining factor is cost, of course, and when cost of mechanical haulage, including operating labor, power, supplies, repairs, depreciation, and interest on the investment, is less than the cost of hand-tramming, the change to mechanical haulage recommends itself. All these items of cost are not always simple to calculate and some of the factors are quite variable. The remaining life of the mine may be too short to warrant change to mechanical haulage and often the remaining life can not be known even approximately.

In some thin, flat-lying but undulating ore deposits, grades may be such that hand-tramming can not be employed, so that some mechanical means of handling and transport would be absolutely necessary.

Further discussion of hand haulage versus mechanical haulage will be included under the caption "Mechanical haulage."

Hand-tramming as an adjunct to animal or mechanical haulage is usually employed to some extent in most ore mines using these methods principally, particularly in development work and for making short transfers on sublevels, and for gathering cars on sidings where trains are made up for motor haulage.

Hand-tramming is still the only haulage method employed in many small mines and prospects. Here due to small output scattered over several levels, short remaining life of the operation, or limited ore reserves, hand-tramming is doubtless the most economical method. There are probably other mines employing all hand-tramming where lack of capital prevents installation of mechanical haulage, even though appreciable reduction in operating costs would result thereby.

For hand-tramming, light cars of the end dump, side dump, or rocker types having a capacity of 16 to 30 cubic feet are commonly used, the 16 and 20 cubic foot sizes being probably the most popular. Track gages are usually 18 to 24 inches, and light rails weighing 12, 16, or 20 pounds per yard are employed. In metal mines the tracks are generally laid on wooden ties. Table 1 gives some data on cars used for hand-tramming as abstracted from the information circulars dealing with mining methods and costs which have been issued from time to time by the United States Bureau of Mines.

Car bodies are usually of steel, though some wood-body cars are still in use. The old type of wooden car had one advantage in that it was easily repaired, whereas the steel body which has been badly bent is difficult to straighten.

Small cars of 16 to 20 cubic feet ($\frac{3}{4}$ to 1 ton) are desirable for hand-tramming. Formerly on the Mesabi iron range, the standard sublevel car was a wooden box car, rigid on the trucks, with an end door, and having a capacity of 36 to 42 cubic feet, or about 2 to $2\frac{1}{2}$ tons of ore (fig. 1). The miners worked on contract in pairs, both in the sublevel drifts and in the slices (top-slicing is the mining method employed). These contractors mucked and hand-trammed their own ore, and by driving the drifts on a $1\frac{1}{2}$ per cent grade in favor of the loads, these cars were handled quite easily. The track terminated at the top of the chute in a curved "dump rail" into which the front wheels of the car dropped, the rear wheels

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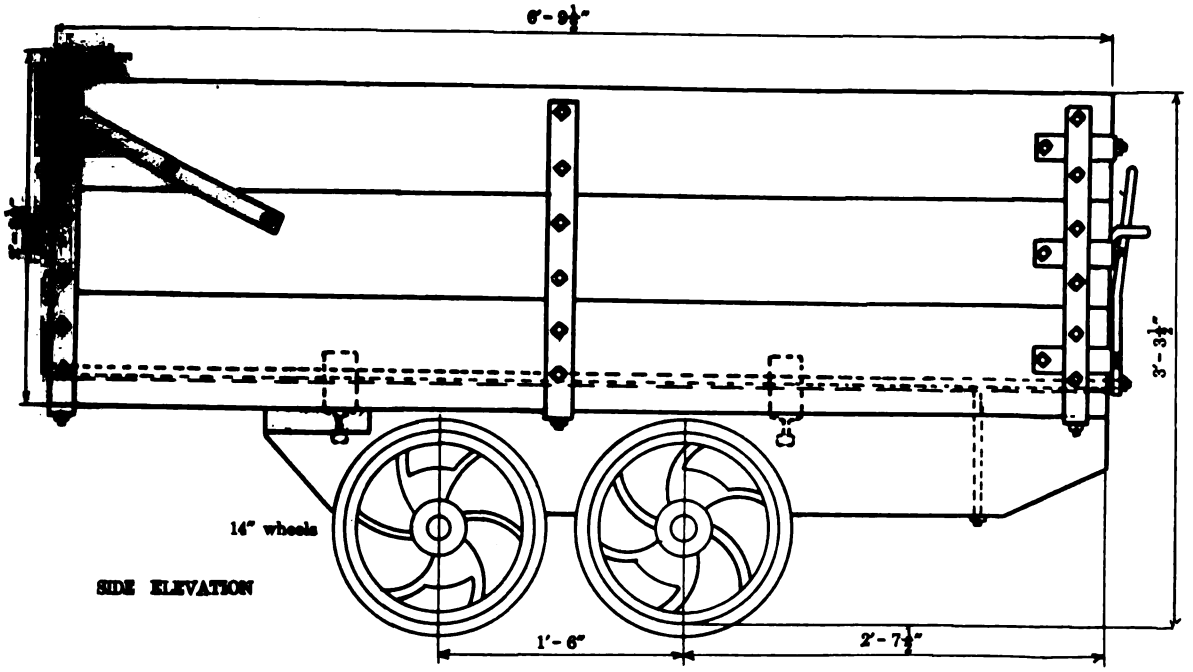

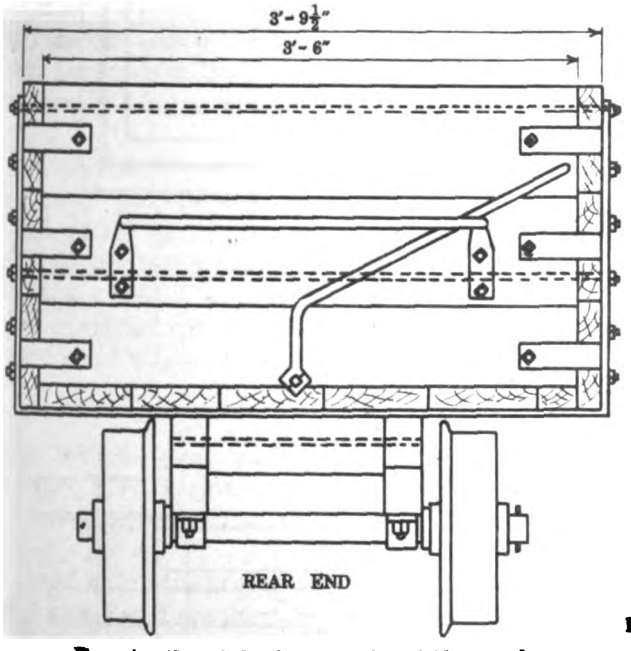

Figure 1. - 42 cu. ft. hand-tram car, box rigid on truck

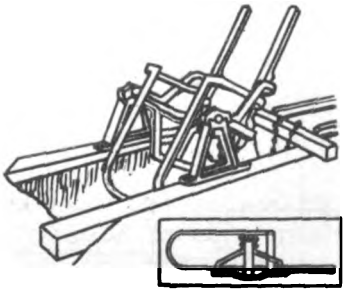

Figure 2. - Cradle dump for 1-ton car (from "Fifty Kinks in Metal Mining", 1920, Engineering and Mining Journal)

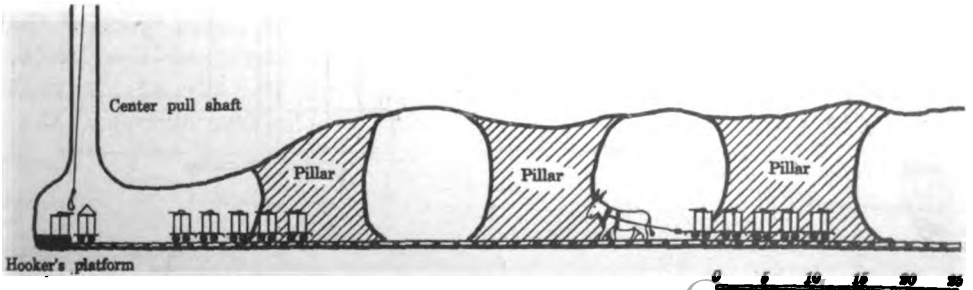

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Figure 3.- Section showing shaft, cans, and hooker's platform, Tri-State district

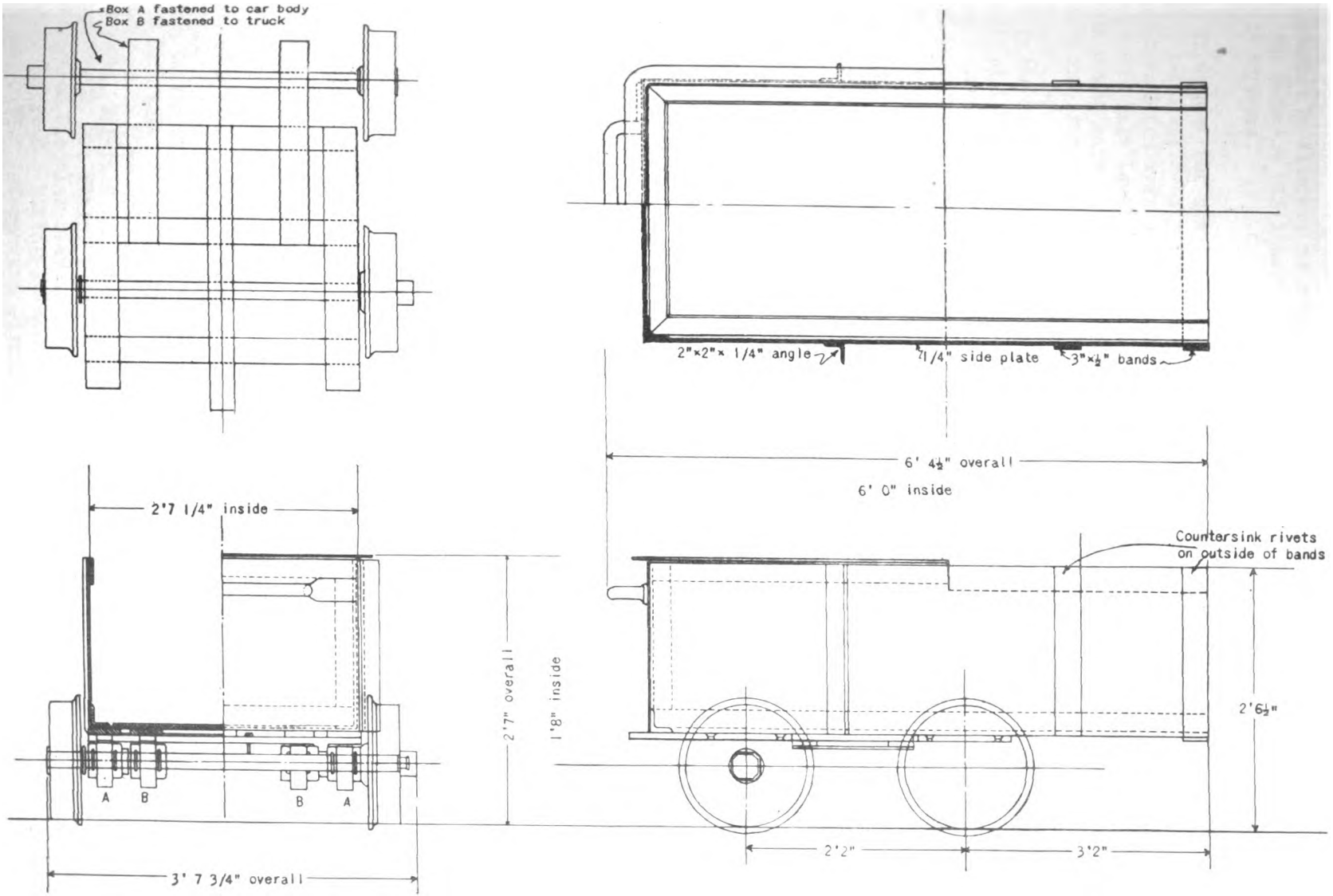

Figure 4.- Hand-tram car

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lifting off the track with the car body. Today these cars have been replaced in many instances by slushers or scrapers which drag the ore from the face to the chute. The cars are still used in other instances, however, but are usually loaded by scrapers.

In some of the small sublevel workings in the southeast Missouri lead district, 1-ton solid-body steel cars are dumped in a cradle (fig. 2) in which the cars are turned end over end[5]. Cars of 2 to 2½ tons capacity are used with motor haulage on the main levels with mules or locomotives for gathering. In development work and in some small, isolated sections of the mines these cars are trammed by hand to and from the gathering points or "loops," as they are locally termed.

In the Tri-State Zinc and Lead district[6] cans set on low trucks and having a capacity of 1,200 to 1,400 pounds are still most commonly used, though some of the larger mines are using cars. Hand-tramming between the face and the siding or "lay-by" is commonly employed where mules or locomotives are used for main-line haulage.

There is probably more mule haulage than motor haulage in this district, though motors are more and more replacing the mules[7]. The cans are placed on a "lay-by" at the shaft, and "bumper" men are employed to handle the cans between the lay-by and the shaft bottom (fig. 3).

At Mineville, N. Y.[8], hand-tramming is employed in the auxiliary shaft areas using 1½ ton cars. The hand-tram car is very low (2 ft. 7 in. above the rails) and is used where hand-loading is employed (fig. 4).

At the Burra Burra mine[9] at Ducktown, Tenn., 2-ton rocker cars are used for hand-tramming in connection with hand-loading from pillar-robbing operations on some of the old upper levels. At Minas de Matahambre, Pinar Del Rio, Cuba[10], considerable hand-tramming is employed for short tramming distances, using 20 cubic foot capacity, end-dump cars equipped with roller-bearing wheels.

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5 Jackson, Chas. F., Methods of Mining Disseminated Lead Ore at a Mine in the Southeast Missouri District. Information Circular 6170, Bureau of Mines, 1929, 21 pp.

6 Netzeband, Wm. F., Method and Cost of Mining Zinc and Lead at Mine No. 2, Tri-State District, Picher, Oklahoma; and Method and Cost of Mining Zinc and Lead at No. 3 Mine, Tri-State District, Crestline, Kansas. Information Circulars 6121 and 6174, Bureau of Mines, 1929.
Banks, Leon M., Mining Methods and Costs in the Waco District. Information Circular 6150, Bureau of Mines, 1929, 10 pp.

7 Netzeband, Wm. F., Method and Cost of Mining Zinc and Lead at No. 1 Mine, Tri-State Zinc and Lead District, Picher, Oklahoma; Method and Cost of Mining Zinc and Lead at Mine No. 2, Tri-State District, Picher, Okla.; Method and Cost of Mining Zinc and Lead at No. 3 Mine, Tri-State District, Crestline, Kansas, Information Circulars 6113, 6121, 6174, Bureau of Mines, 1929.
Keener, Oliver W., Method and Cost of Mining at Barr Mine, Tri-State Zinc and Lead District. Information Circular 6159, Bureau of Mines, 1929, 11 pp.

8 Cummings, A. M., Method and Cost of Mining Magnetite in the Mineville District, New York. Information Circular 6092, Bureau of Mines, 1928, 12 pp.

9 McNaughton, C. H., Mining Methods of the Tennessee Copper Co., Ducktown, Tenn. Information Circular 6149, Bureau of Mines, 1929, 17 pp.

10 Richert, George L., Mining Methods at Minas De Matahambre, Matahambre, Pinar Del Rio, Cuba. Information Circular 6145, Bureau of Mines, 1929, 18 pp.

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At Ray, Arizona[11], hand-tramming is employed in mining small bodies of fringe ore which are too high above the main level to permit the use of either the motor system or the modified motor system and which do not have sufficient vertical thickness to warrant application of the sublevel system. The ore is loaded from chutes into 1-ton cars and is trammed by hand for short distances to transfer chutes.

At Globe, Ariz.[12], large quantities of water are encountered in opening up a new level and no type of motor haulage is practicable until the level is drained sufficiently to confine the water to a ditch. Hand-trammed, 20 cubic foot, side-dump cars are used on these new levels. Hand-tramming is also resorted to sometimes for short distances in filling operations, where cars of waste are trammed from a siding to the top of the stope.

At the Hecle mine[13], hand-tramming is employed in the stopes both for transferring the ore from the face to the ore passes and for spreading waste fill.

At the Harmony Mine in Idaho[14], hand-tramming in 16 cubic foot cars is employed on sublevels for transferring ore.

Hand-tramming is employed at Cananea[15] as an adjunct to motor haulage and for this purpose 1-ton capacity end-dump cars weighing 1,060 pounds are used. On one level the average hand-tramming distance is 800 feet, and 25 tons per trammer shift is the average output. Some trammers will make as high as 40 tons. The trammers are paid a flat price per car when tramming from stope chutes.

At the United Verde Extension[16] the car used for hand-tramming is of 16 cubic foot capacity.

Track. - As stated above, light rails and narrow gage tracks are the rule for hand-tramming. The drifts are usually carried on a good grade in favor of the loads so that loaded cars can be pushed with minimum effort. Frequently these grades are such that once started, the cars will run by gravity. Theoretically the proper grade for hand-tramming is such that when the loaded car is started it will keep moving with little or no assistance on the part of the trammer. With easy-running, well-oiled, and well-maintained cars of the ordinary types and weights, on good track, this grade is made about .67 per cent. With average track and car conditions it is about .85 per cent, and for poor conditions about 1.4 per

11 Thomas, Robert W., Mining Practice at Ray Mines, Nevada Consolidated Copper Co., Ray, Arizona. Information Circular 6167, Bureau of Mines, 1929, 27 pp.

12 Shoemaker, A., Mining Methods at the Old Dominion Mine, Globe, Arizona. Information Circular 6237, Bureau of Mines, 1930, 21 pp.

13 Foreman, Charles H., Mining Methods and Costs at the Hecla and Star Mines, Burke, Idaho. Information Circular 6232, Bureau of Mines, 1930, 21 pp.

14 Gardner, R. Duncan, Mining Practice at Harmony Mines Co., Baker, Idaho. Information Circular 6240, Bureau of Mines, 1930, 8 pp.

15 Catron, William, Mining Methods, Practices, and Costs of the Cananea Consolidated Copper Co., Sonora, Mexico. Information Circular 6247, Bureau of Mines, 1930, 41 pp.

16 D'Arcy, Richard L., Mining Practice and Methods at the United Verde Extension Mining Co., Jerome, Arizona. Information Circular 6250, Bureau of Mines, 1930, 11 pp.

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cent. In practice it is often the case that track conditions vary from good to bad in different parts of a mine or even on different sections of the same haulageway and that the effort required to move different cars varies. Experience with trammers would seem to indicate that there is considerable difference in cars which is probably not all imagination on the part of the trammer. The net result is that cars have to be braked on some sections of track and are pushed with difficulty on others. Often too little attention is given to track conditions where hand-tramming is employed, whereas the track should receive as much attention as with motor haulage. In many mines the mucker also does the tramming where hand-tramming is employed, and if the workmen are obliged to expend their strength and energy in "bulling" stiff cars over poorly laid and maintained tracks their efficiency as muckers is seriously impaired. Closely spaced, well-tamped ties to prevent sagging of the rails; proper gage clearances between the rail and flange of the wheel on straight tracks, curves, and switches; and clean tracks are as necessary with hand-tramming as with motor haulage and will pay dividends in the long run.

Animal Haulage

Mules and horses are still employed to some extent for underground haulage, though they are rapidly being replaced by motors in most districts. They are usually employed for hauling trains of cars of the size and type used for hand-tramming and are also used for gathering and spotting larger cars which are handled by motors on the main haulageways. The most logical application of mule haulage is probably in making short hauls where there are unavoidable bad grades against which hand-trammers could not work and yet not so severe that rope haulage is necessary.

In southeast Missouri, mules are used to handle 2½ ton cars between the loading face and the "loops" or sidings. In this district loading is largely done by power shovels; the shovel operator spots his own cars and uses a mule for this purpose[17]. In other mines[18] 2-ton cars are spotted by motor and 1-ton cars by hand.

In the Tri-State zinc and lead district, mules are extensively employed for main-line haulage and for spotting cars at the face. In the larger mines in this district where the hauls are long, locomotives are coming into use more and more.

At one mine in Tennessee 2-ton cars are loaded from chutes or from muck piles and are hauled by mules in trains of 2 to 4 cars to the shaft. The operators consider that the short remaining life of the mine does not warrant installation of motor haulage, though motor haulage would doubtless be more economical.

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17 Jackson, C. F., Information Circular 6170, cited.

18 Poston, Roy H., Method and Cost of Mining at No. 8 Mine, St. Louis Smelting and Refining Company, Southeast Missouri District. Information Circular 6160, 1929, 22 pp.

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At the Isle Royal mine in Michigan, hand-tramming is employed for a short distance when starting to develop a new level, and as the drifts get longer mules are used to the end of the level. Stoping starts at the ends of the level and retreats toward the shaft. As soon as stoping is begun 4-ton, 48-cell, storage-battery locomotives replace mule haulage. For hand and mule haulage, 2½-ton cars are used which are replaced by 5-ton end-dump cars for locomotive haulage.

Mechanical Haulage

Mechanical haulage in ore mines is of three general types: (1) Locomotive; (2) scraper or slusher; (3) rope haulage. Conveyor systems have come into general use in coal mines, so that four principal types of mechanical transport are used in coal mining.

For underground haulage in ore mines locomotives are generally driven by electric motors, sometimes by compressed air, and very infrequently by gasoline motors. Electric locomotives are of four different types: (1) Trolley; (2) trolley with cable-reel attachment; (3) storage battery; and (4) combination trolley and battery (rarely used in metal mines). It is not the purpose of this paper to discuss equipment from a mechanical standpoint, but to consider briefly the applications of types of equipment to different conditions; for this reason details of locomotive and car construction are not included.

Scraper work is here considered as a part of the underground transport system because the scraper, although usually thought of as a loading machine, serves equally well the purpose of a conveying machine, though the distances over which it operates may be short. As a conveying machine it is usually employed as an adjunct to the regular haulage system for transporting ore from the stope face to chutes or to cars.

In many mines trolley locomotives are used for main level haulage while smaller storage-battery locomotives are employed on intermediate levels. In yet other instances large trolley locomotives are employed for the longer main-line hauls, while the cars are gathered and made up into trains by smaller locomotives.

In a previous paragraph some observations were made upon the desirability of changing from hand to mechanical tramming. It was suggested that in general, for mines of over 300 or 400 tons daily output (sometimes less), a change to mechanical haulage would be warranted, though certain conditions might alter this.

As an example of the advantages of mechanical haulage in even a small mine and with comparatively short hauls may be cited the following: Of the output of 400 tons per day divided between two shifts, about 300 tons came from stope chutes, the average length of haul being only about 500 feet and the maximum 750 feet. When hand-tramming from the stope chutes with 1-ton cars, 8 men per shift were required to load, tram, and dump the cars, 16 men in all.

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Electric haulage was installed, using a storage-battery locomotive and 3-ton Granby cars, in anticipation of a considerably larger output later on. Chutes were widened from 42 inches to 56 inches, as the muck was very coarse, though it was mixed with some sticky, fine ore. When motor haulage was begun, the 300 tons from the stope chutes with some development ore was trammed in 2½ hours by three men, one motorman and two loaders, giving a labor cost of a little less than one man-shift for 300 tons. The cost of loading and tramming by hand had averaged 22 cents per ton. The cost of loading and tramming with motor haulage was 5.2 cents per ton, including labor and power. To the latter cost should have been added depreciation to give the total cost, but the margin in favor of motor haulage was still large.

Since no two mines are just alike and conditions usually differ widely, the combinations of haulage methods and equipment which will give most economical results vary with the conditions to be met. In arriving at the best solution of an underground haulage problem, certain more or less intangible factors must be considered along with such factors as first cost of equipment, direct operating costs, repairs, and maintenance. Among such factors may be named: Flexibility of equipment in its application to possible changes in conditions; adaptability of a new type or size of equipment to use with other equipment already being used in which a large investment may already be tied up, and the scrapping of which would entail a large loss; and the results of using several types and sizes of equipment upon stock-room inventory of parts; etc.

In old mines it is often necessary in deciding upon new equipment to compromise between that which would give the lowest operating cost and that which would best adapt itself to use with equipment already on hand.

With greatly increased output or length of haul it would usually be desirable to go to larger cars and locomotives, but such a change might necessitate widening and retimbering drifts and changing a large number of chutes at unwarranted cost. Changes in type of car may require changes in shaft pockets, which introduces another factor.

At one mine studied in the course of the bureau's investigations of mining methods,[19] the haulage equipment now in use tells an interesting story of the changes made over a period of years. Here 2-ton rocker-type cars are used for hand loading and tramming in pillar-robbing operations on some of the old upper levels, together with end-dump cars of 4-ton capacity for motor haulage. The next car introduced was a 5-ton Granby type used on the 12th and 14th levels. On the 16th or bottom level 7-ton end-dump cars are used for dumping directly into 7-ton skips. As the lower levels have been opened up it has been possible to provide for use of larger equipment without any expense for changing over haulageways and chutes, and probably the older equipment will be worn out on the upper levels. In this instance then, the change of equipment was accomplished without scrapping any old but still serviceable cars. Here too, it has been possible to adhere to the same track gage (24 inches) on all levels, whereas had they started with a narrower track gage it would probably have been advisable to use a wider gage on the lower levels.

19 McNaughton, C. H., Mining Methods of the Tennessee Copper Company, Ducktown, Tenn. Information Circular 6149, Bureau of Mines, 1929, 17 pp.

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Tables 2, 3, and 4 show some of the details of haulage equipment and tracks as given in information circulars on mining methods and costs already published by the Bureau of Mines and indicate to some extent the prevailing preferences as to types and sizes of cars and locomotives, track gages, etc.

Cars. - As already stated, the size of car depends, or should depend, to a large extent upon the tonnage handled and the length of haul. If cars are to be hoisted on cages, the size of shaft compartments will determine the maximum size of car. The size of chunks handled has an important bearing upon the size and shape of car and also upon the method of dumping best adapted to the given operation. The size of car should be such as to best adapt itself to the method of loading employed.

For hand-loading, the car should be low in order that a minimum shoveling effort may be required. This often means that a car of small capacity must be used, since to get large capacity, the low car must be wide or long, which in turn may affect the width of the drifts or the minimum allowable degree of curvature of the tracks. On the other hand, certain types of cars combine low height with relatively large capacity. Thus a rectangular body rigid on the trucks (fig. 5) has a larger capacity for its height, length, and width than a gable-bottomed car or an end or side door type of car which tips up about a shaft on the trucks. Hence the method of dumping affects the capacity for given over-all clearance dimensions.

Where scrapers or other mechanical loaders are employed to load directly into cars, it is desirable that the cars have a large capacity in order that only the minimum time may be lost by the scraper while shifting and spotting cars. The cars should be low enough to allow room for a slide above and for the scraper to work over the slide and below the top of the drift or stope. Length and width must be proportioned so that the scraper will fill the ends and sides and at the same time not spill the ore over the track and roadway. These proportions will depend upon whether the scraper loads from the side or the end of the car.

In loading rough muck (large chunks) from chutes, it is a decided advantage to have wide chutes with fairly high openings. In one instance with which the writer is familiar, the change from a 42-inch opening (width) to 56 inches resulted in doubling the loading rate from the chute. Since in loading from chutes the ore is usually loaded over the side of the car, a wide chute opening means a relatively long car. If capacity is gained by widening the car, the lip of the chute generally has to be raised in order to fill the side of the car away from the chute properly.

The nature of the ore handled has a bearing on the dumping method as well as on the size of the car. Fine, dry ore will sift out around doors if they are not tight, dirtying the tracks and roadways, and entailing expense for keeping them cleaned up. Solid car bodies without doors (fig. 5) are well adapted to this kind of ore but require a rotary dump or cradle for dumping. If the output is scattered over several levels and is small from each level, the cost of installing a dump on each level is apt to be prohibitive. When the production from one level is large a rotary dump and solid-body cars make a very efficient and desirable installation.

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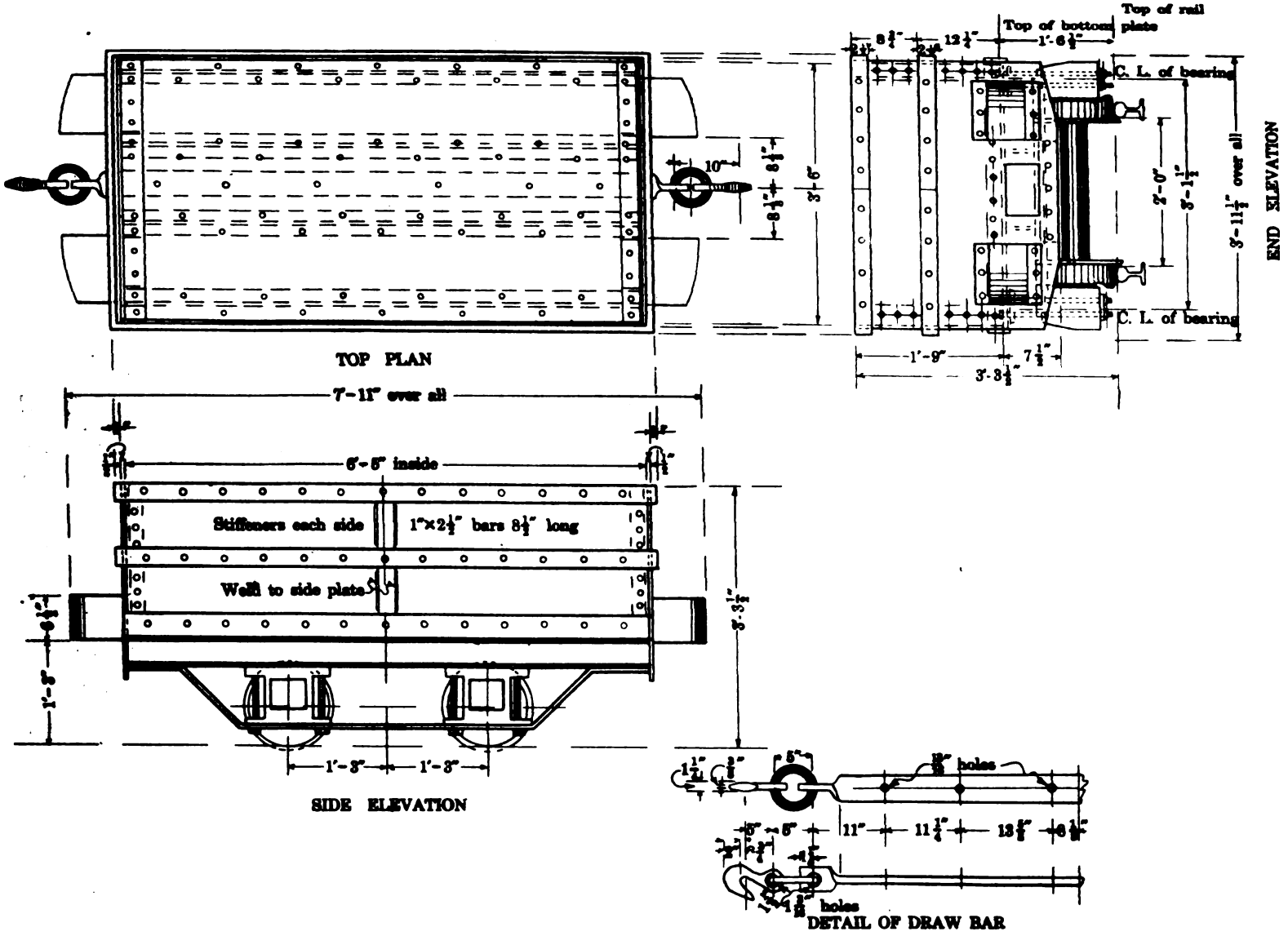

Figure 5.- Two-ton solid body, all-steel mine car with railroad-type journal box

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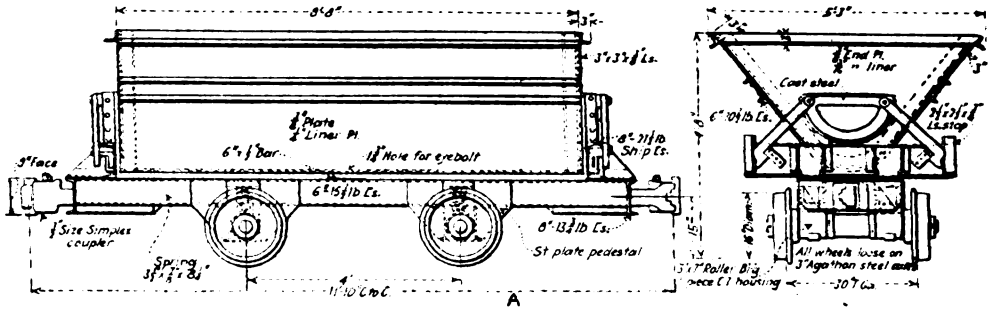

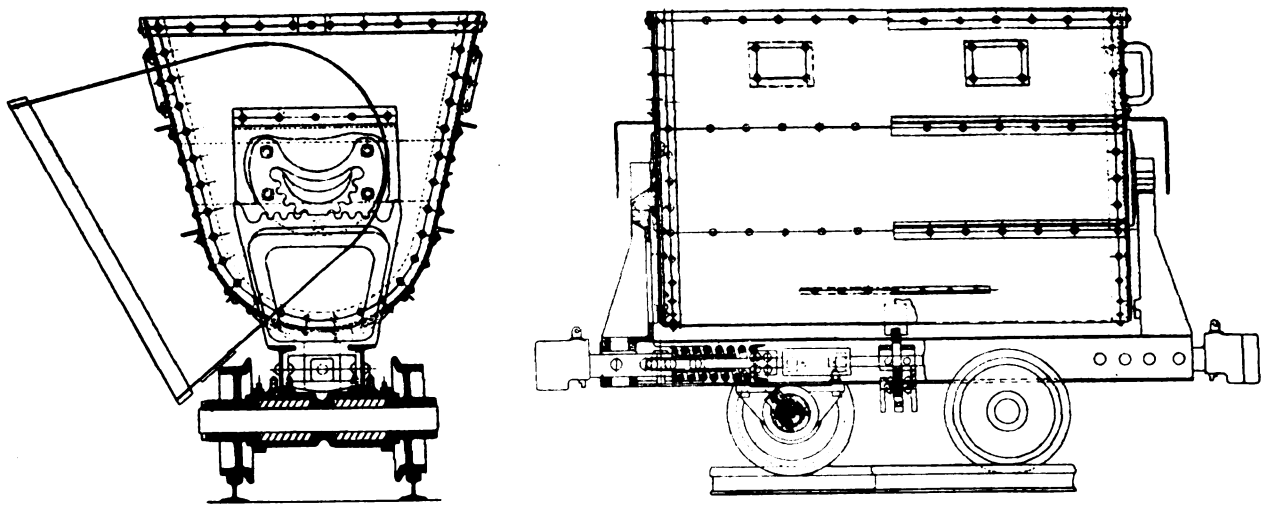

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Figure 6.- Types of rocker-dump cars: A, Sketch of 76-cubic-foot rocker-dump ore car used on mainline tracks; B, 30-cubic-foot mine car

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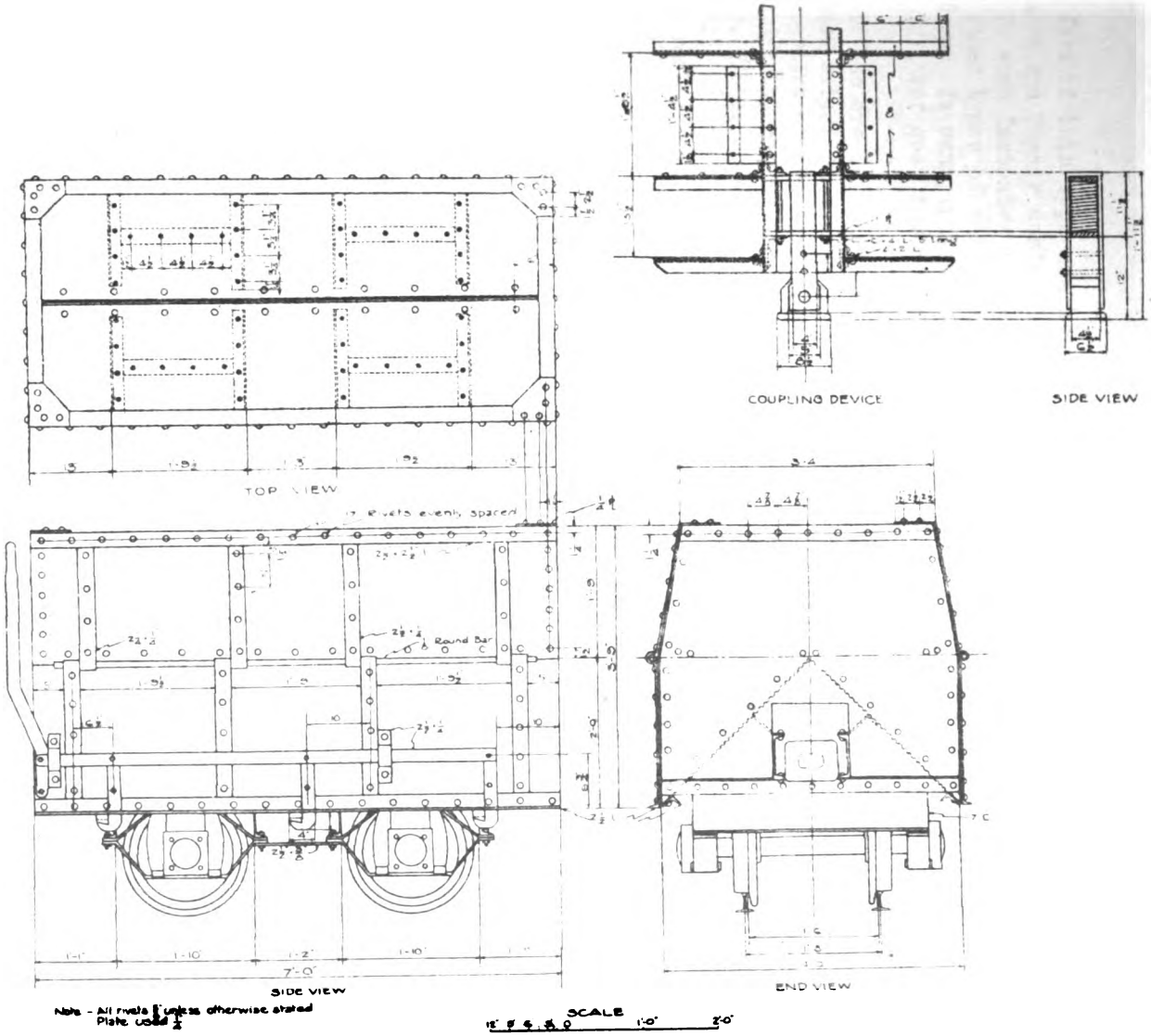

Figure 7.- Four-ton, gable-bottom car, Cananea Consolidated Copper Co.

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Cars of this type are lower in first cost, are sturdy in construction, maintenance and repair costs are comparatively low, and they are economical of space. In some instances the saving in first cost of the cars as compared to that of some other types of cars, may more than pay for the cost of installing the rotary dump. In many instances the rotary dump has been responsible for direct savings in labor cost for dumping as well.

If the ore is fine, wet, and sticky, the solid-type car is perhaps not always best suited to carry it because of the trouble in dumping and in cleaning out the corners of the car, though certain types of rotary dumps can be operated so as to jar the car by bumping the dump stop several times while the car is tipped up. This, however, may not always be the best thing for the running gear of the car. At one mine[20] where the ore from two or three chutes was very sticky and where rectangular solid-body cars were used, sheets of oiled paper were provided which just fitted the bottom of the car. Before each loading a sheet of this paper was laid in the bottom of the car, and upon dumping in the rotary dump, the ore came out freely, leaving the bottom of the car clean and ready for the next load.

For sticky ore, rocker cars with rounded bottoms (fig. 6) or gable-bottomed cars (figs. 7,18 and 20) have certain advantages. The former are easily cleaned by hand as there are no corners in which the ore accumulates, and the latter can be easily cleaned by slamming the doors a few times or by scraping with a shovel or flat blade. Neither of these types are as economical of space as the solid-body car, and the gable-bottomed car in particular is subject to high repair costs. Either type may be quickly dumped in trains without uncoupling.

Dumping. - The time-tested, small, end-dump car (fig. 8) has admitted advantages for hand-tramming. It is very flexible and when equipped for swinging to either side is especially so. For use with motor haulage it has certain obvious disadvantages, as each car has to be uncoupled from the train and dumped separately. This disadvantage is somewhat minimized in larger cars of this type, as fewer couplings and uncouplings are necessary for the same tonnage. With large end-dump cars, however, it is necessary to provide some mechanical means of dumping, such as an air-jack or small hoist and chain.[21]

Side-dump, side-door tipping, gable-bottomed, or rocker cars may be dumped without uncoupling from the train. The side-door tipping type can not be dumped conveniently with the train in motion, and it is usually necessary to stop each car over the pocket. Rocker and gable-bottomed types, however, may usually be dumped with the train moving slowly.

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20 Jackson, Chas. F., Methods of Mining Disseminated Lead Ore at a Mine in the Southeast Missouri District. Information Circular 6170, Bureau of Mines, 1929, p. 18.

21 McNaughton, C. H., Information Circular 6149, cited.

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When using a mechanically operated rotary dump (fig. 9) the cars may be dumped without uncoupling by using swivel couplings. With most types of gravity-operated rotary dumps (fig. 10) it is necessary to uncouple the cars, though in some types chain couplings may be used which permit dumping without uncoupling. Rotary dumping is fairly rapid, especially if the dump is built to handle two or more cars at a time. Where ample capacity is provided in skip pockets or other dumping point, the train crew can attend to the dumping without loss of time.

Bottom-dump cars (fig. 11) are well suited for rapid work, as they can be dumped without uncoupling and with the train in motion. They have the disadvantage of leaking when fine muck is handled unless kept in perfect condition.

Probably the best car for large capacity and speed in dumping is the Granby-type car (fig. 12) which when dumped by running it over a ramp, as it is designed to do, can be dumped with the train traveling at fairly high speed and without labor other than that provided by the train crew. Where dumped by air jack or by hoist and chain one of its principal advantages is lost. It is almost impossible to dump it by hand, which is a disadvantage in case the power goes off. It is rugged in construction, can be used to handle rough muck but is necessarily heavy. Also, it is not as economical of space as some other types of cars. As the Granby is a rectangular, flat-bottomed car, trouble is sometimes experienced with it in handling sticky ore, requiring frequent cleaning by hand. Rapid dumping is perhaps its main advantage; and although the first cost of the car is high, the rapidity with which it may be dumped and returned for its next load may result in fewer cars being required than where some other types are employed. With some types of cars it is customary for the locomotive to leave a loaded train at the shaft, returning inside with an empty train while the loads are being dumped by the shaft men. Where Granby-type cars are used and ample pocket capacity is provided, the dumping time is so short that an extra train of cars is not required and the trip can be dumped without uncoupling in less time than it would require to switch out the loaded train and couple up with the standing empty train of other types of cars.

From the foregoing brief discussion then, the type and size of mine car should be governed by rate of output and length of haul; size of existing or proposed drifts, crosscuts, and tunnels and, if cars are hoisted, the size of shaft and cages; size of muck and its physical characteristics; method of loading employed; method of dumping; method of hoisting and, where skips are used, storage capacity of skip pockets or (and) transfer raises.

Table 1, though covering only a few mines, indicates a preference for end-dump cars of 16 to 20 cubic foot (roughly 0.75 to 1.5 tons) capacity for hand-tramming.

Reference to Table 2 shows that for motor haulage there is a wide variation in practice as to size of car. Of 27 mines listed, 7 employ end-dump cars ranging in size from 20 cubic feet, or about 1 ton, to 7 tons capacity; 4 employ rectangular tip-dump cars with side doors, of 1 to 5 tons capacity; 8 use side-dump, gable-bottomed cars of 2 to 7 tons capacity. Rocker-dump cars of 1 to 6

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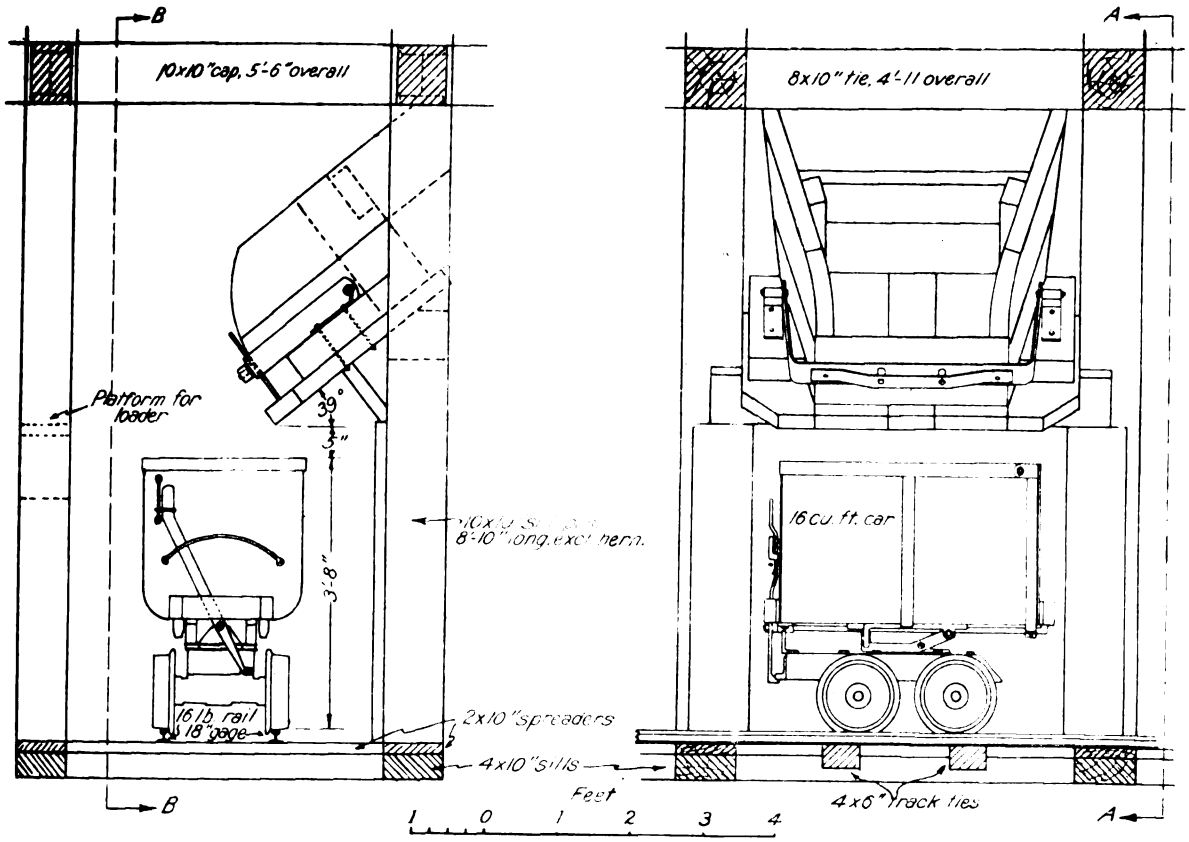

Figure 8.- United Verde chute gate and 16-cubic-foot end-dump car

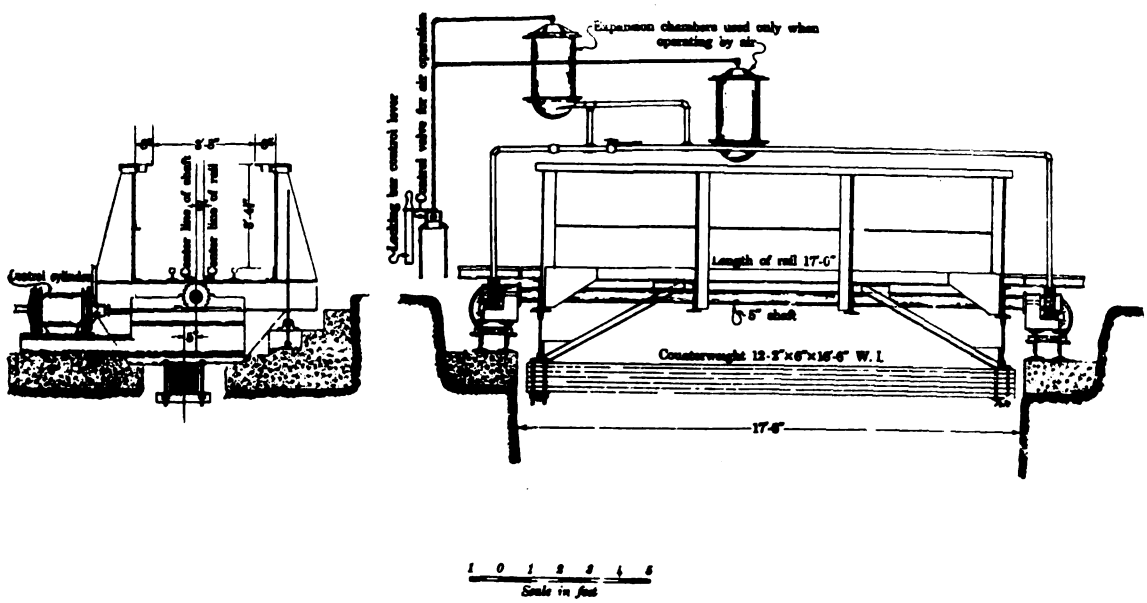

Figure 9.- Two-car shaft-type rotary car dumper

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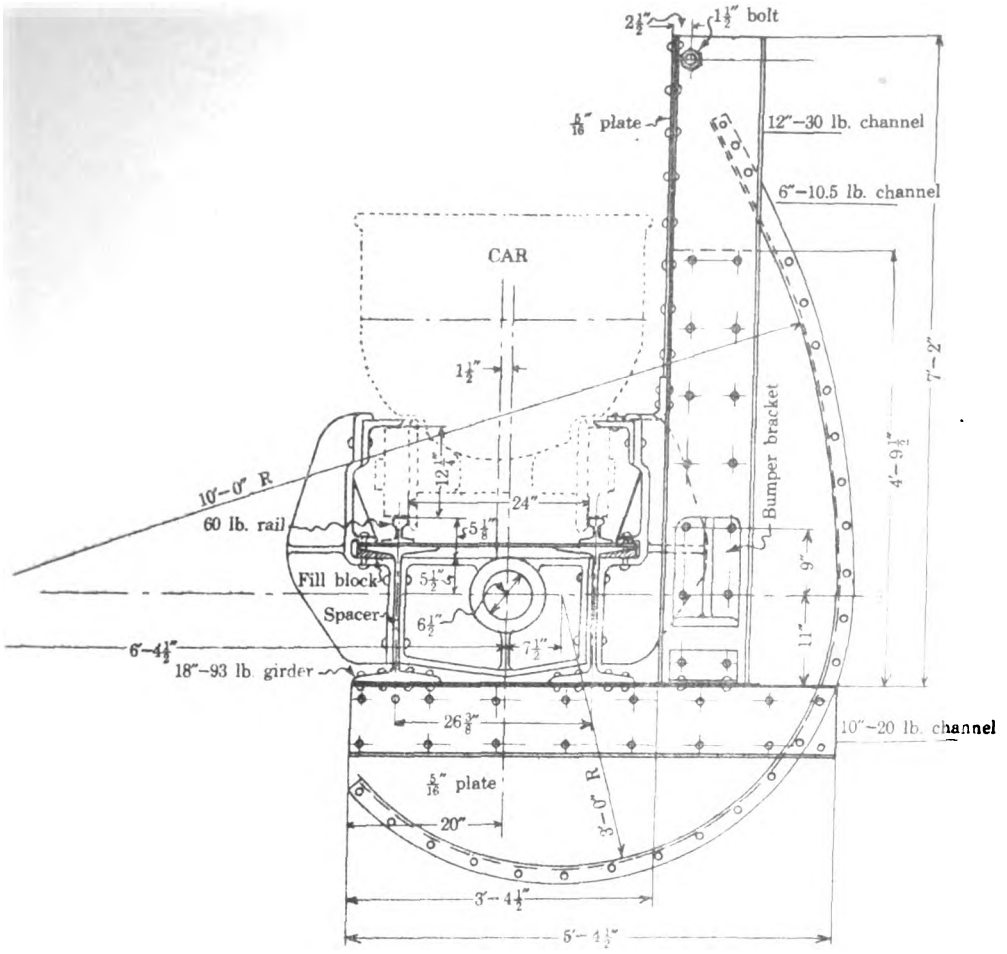

Figure 10.– End view of gravity rotary dump

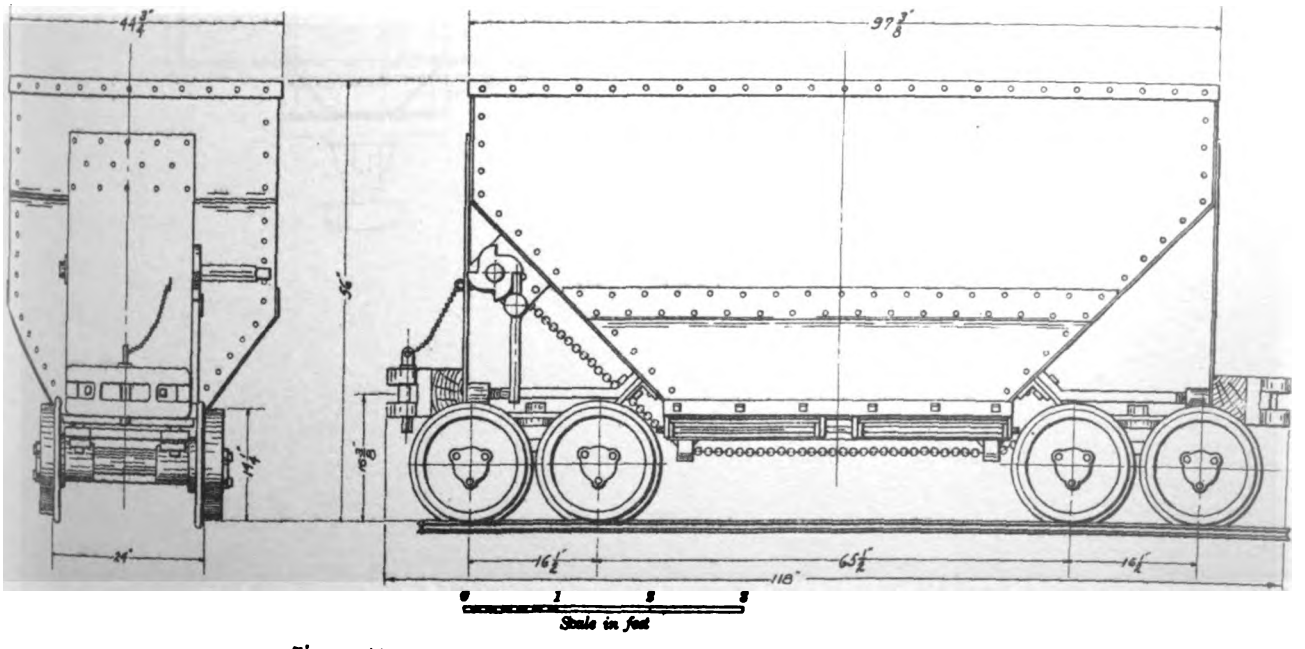

Figure 11.– Hopper-bottom ore car, 80-cubic-foot capacity

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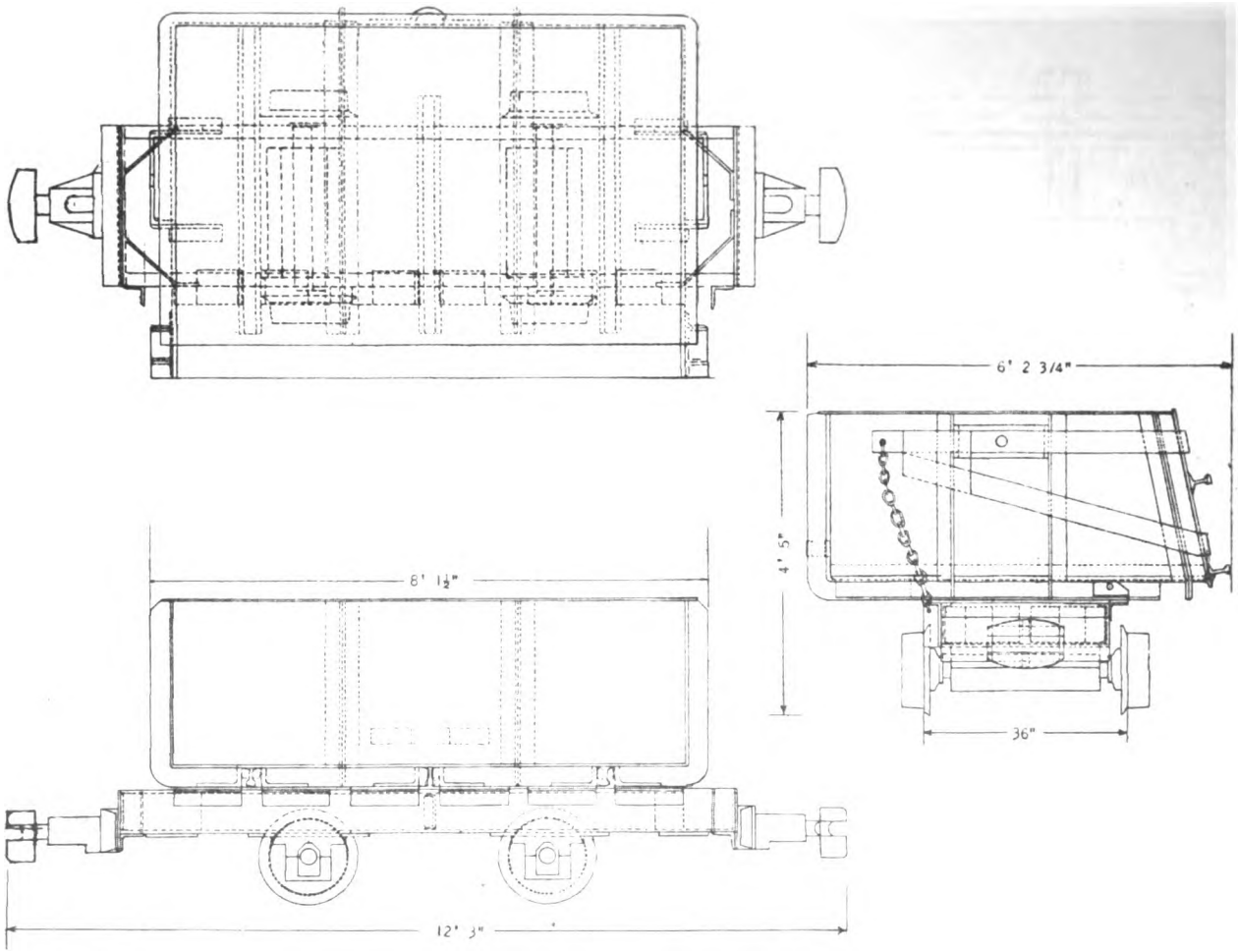

Figure 12.- Granby-type car

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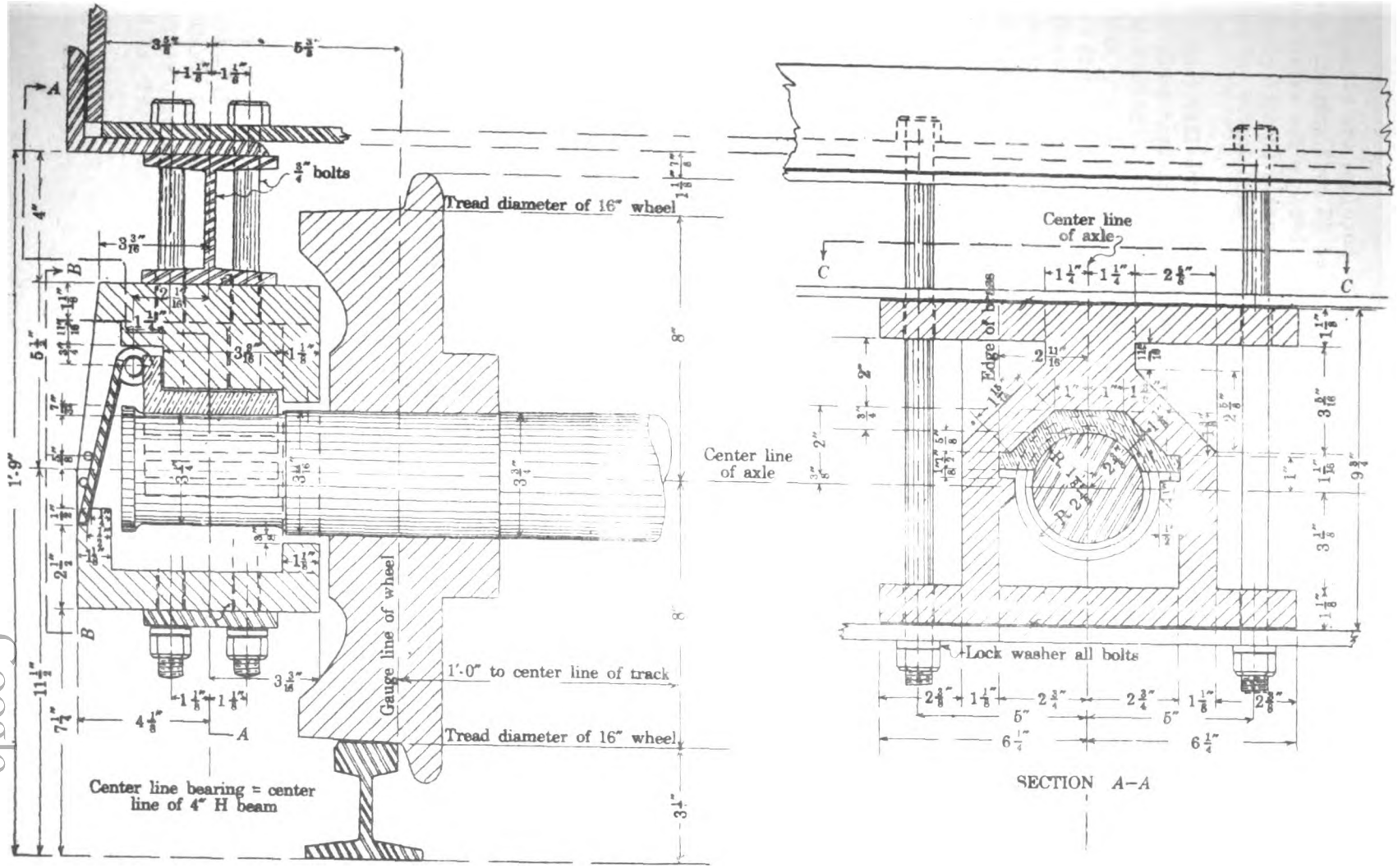
3/4" bolts
Tread diameter of 16" wheel
Center line of axle
Gauge line of wheel
1'-0" to center line of track
Tread diameter of 16" wheel
Center line bearing = center line of 4" H beam
1'-9"
Edge of brass
Lock washer all bolts
SECTION A-A
SECTION ON CENTER LINE

Figure 13.- Journal box and bearing for mine car

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tons capacity are employed at 6 mines and seem to be gaining in favor, especially in sizes ranging from 2½ to 4 tons. Seven mines use solid cars, rigidly secured to the trucks and emptied in rotary dumps, of capacities ranging from 1 to 5 tons. The Granby type in sizes from 3½ to 5 tons is used at two of the mines, and one employs the bottom-dump type of car in two sizes - 5 and 7 tons.

Most well-equipped mines now use roller-bearing cars. Recently, however, several mines have changed from roller bearing to the outside-journal, railroad type of bearing[22] (fig. 13). On the other hand, one mine[23] has recently changed from this type of bearing to tapered roller bearings, at the same time changing the car from the solid-body rotary-dump to the side-dump type. It may be noted as significant that the outside-journal type of bearing is used at the tabulated mines on cars which are dumped in rotary dumps or on heavy Granby-type cars. With cars of these types it is probable that the roller-bearing cars will not stand up well under the sudden stresses applied when dumping and that preference has thus been given to the outside-journal type of bearing as being more rugged and requiring less attention and care.

Locomotives

As already stated, it is not the purpose of the present paper to discuss the mechanical construction of locomotives or the details of motors, controls, brakes, etc. In Table 4 are listed incomplete data on locomotives at a number of mines which have been described in Bureau of Mines publications.

Of the 26 references there listed, 11 use only trolley-type locomotives, two of which employ trolley with cable-reel attachment. Three use only storage-battery locomotives, and one uses compressed-air locomotives. One large mine which had used compressed-air locomotives for many years has changed to electric locomotives. Eleven of the mines use both trolley and storage-battery locomotives. Where a combination is in use, the trolley type is usually employed for the long hauls and large trains, and the battery type for advance development, in isolated sections of the mine, or for gathering cars and making them up into trains on a siding whence the main haulage locomotive takes them over the main line. With trolley locomotives the current usually returns through the rails which are bonded at the joints. At the Park-Utah mine. (Information Circular 6190.) two wires are carried, the second wire being for return. Here there is a large amount of water to contend with in the haulageway.

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22 Cummings, A. M., Method and Cost of Mining Magnetite in the Mineville District, New York. Information Circular 6092, Bureau of Mines, 1928, 12 pp.
Jackson, Chas. F., Information Circular 6170, cited.
Shoemaker, A. H., Work cited.
Catron, William, Work cited.

23 Stoddard, Alfred C., Mining Practice and Methods at Inspiration Consolidated Copper Company, Inspiration, Arizona. Information Circular 6169, Bureau of Mines, 1929, 23 pp.

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Both the trolley and battery types have their proper places in the haulage system. For large capacity and long hauls, the trolley locomotive is justly favored. Storage-battery locomotives for this type of service require a large ampere-hour capacity and unless the ore comes in surges so that there are slack times during the working period (which is seldom regularly the case), during which batteries can be put on charge or there is sufficient interval between haulage shifts for this purpose, the batteries are likely to run too low and be discharged below the desirable or safe limit. For heavy service it is often necessary to have two sets of batteries for each locomotive so that one may be on charge while the other is in use.

In low drifts and opposite loading chutes or in heavily timbered drifts, live trolley wires introduce a certain hazard, which is generally recognized. Careful guarding of the wires is necessary. The expense of installing trolley wires and bonding the rails in haulageways which have a short life are other factors against the trolley locomotive. This is sometimes overcome by using a cable-reel attachment where the tramming distance away from the main line is not over 500 feet (1,000-foot cables are in use, but this length is cumbersome).

The battery locomotive has the advantage of being able to travel over the rails under a self-contained source of power without trolley wires, but must return at definite intervals to the charging station. It is thus very flexible up to the limit of its ampere-hour capacity.

In small mines or where the output is scattered over several levels, the battery locomotive of the so-called "trammer" type has strong points in its favor. It will go on the ordinary mine cage and can thus be quickly moved from level to level where needed. It will do several times the work of a hand-trammer, and its operating cost is low provided it is inspected frequently by a competent mechanic and kept in repair.

The battery locomotive has a higher first cost than a trolley locomotive of the same capacity, requires the installation of a charging station, and needs more skilled attention to keep it in proper working condition. Also the rate of depreciation is higher, due to the batteries, than for the trolley locomotive. These disadvantages are often more than offset, however, by its flexibility. In some cases the fact that it is charged between shifts when the other electrical load is lightest and does not pull peak loads when starting may be of sufficient importance to be given consideration.

The compressed-air locomotive is not widely used any longer. It was first introduced to overcome some of the objections of the trolley locomotive. It operates under self-contained power, and the absence of bare, charged wires eliminates the hazards of fire and electric shocks. An expensive, multistage compressor installation is required, however, and the cost of high-pressure air lines to the charging stations is high. These stations are located at advantageous points to which the locomotive must return for frequent charging. In some warm mines it might be thought that the exhaust air would be advantageous in improving ventilation, but this effect is probably more than offset by the clouds

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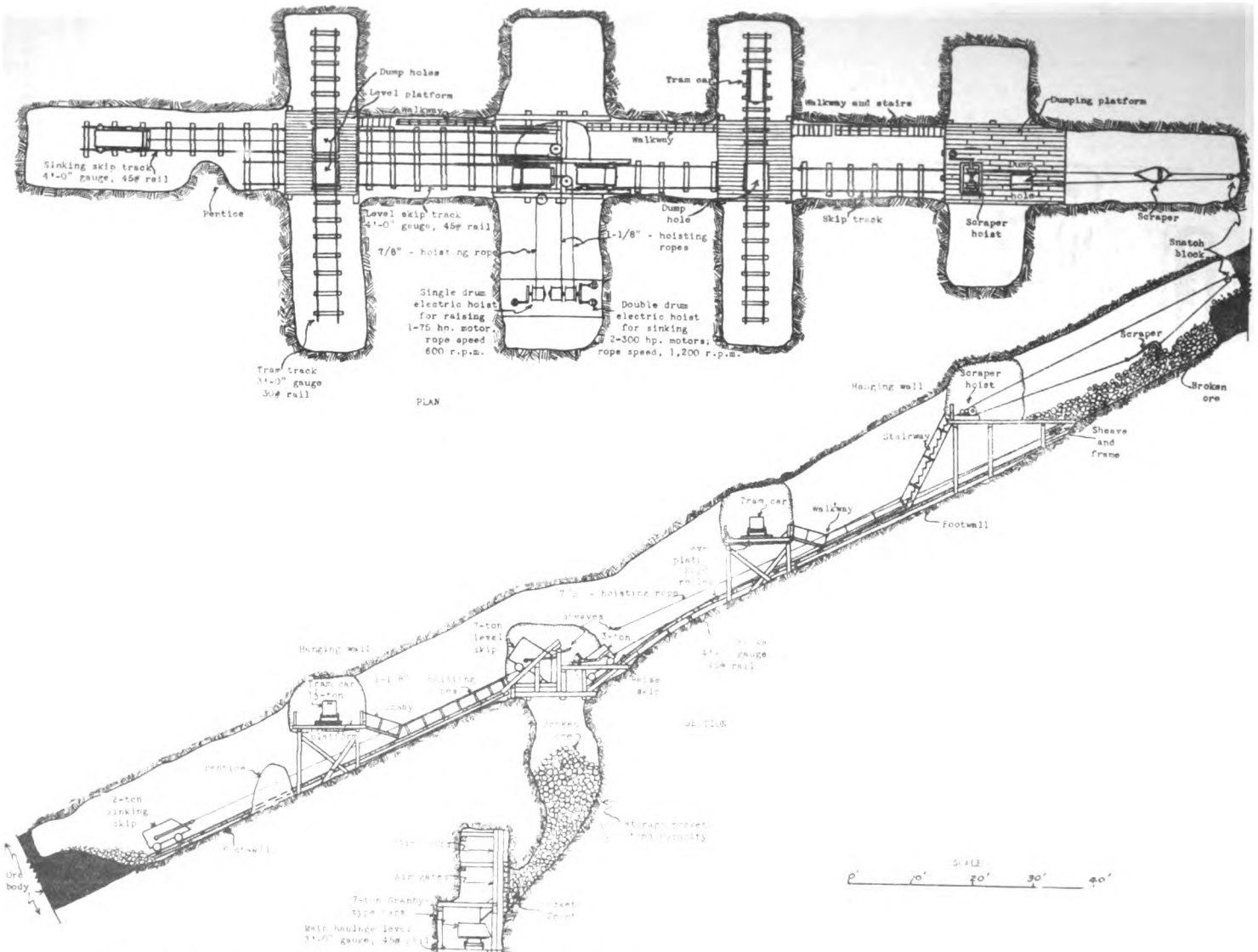

Figure 14.- Auxiliary shaft, showing typical method of sinking and raising in the ore body and of hoisting and lowering ore to the main haulage level

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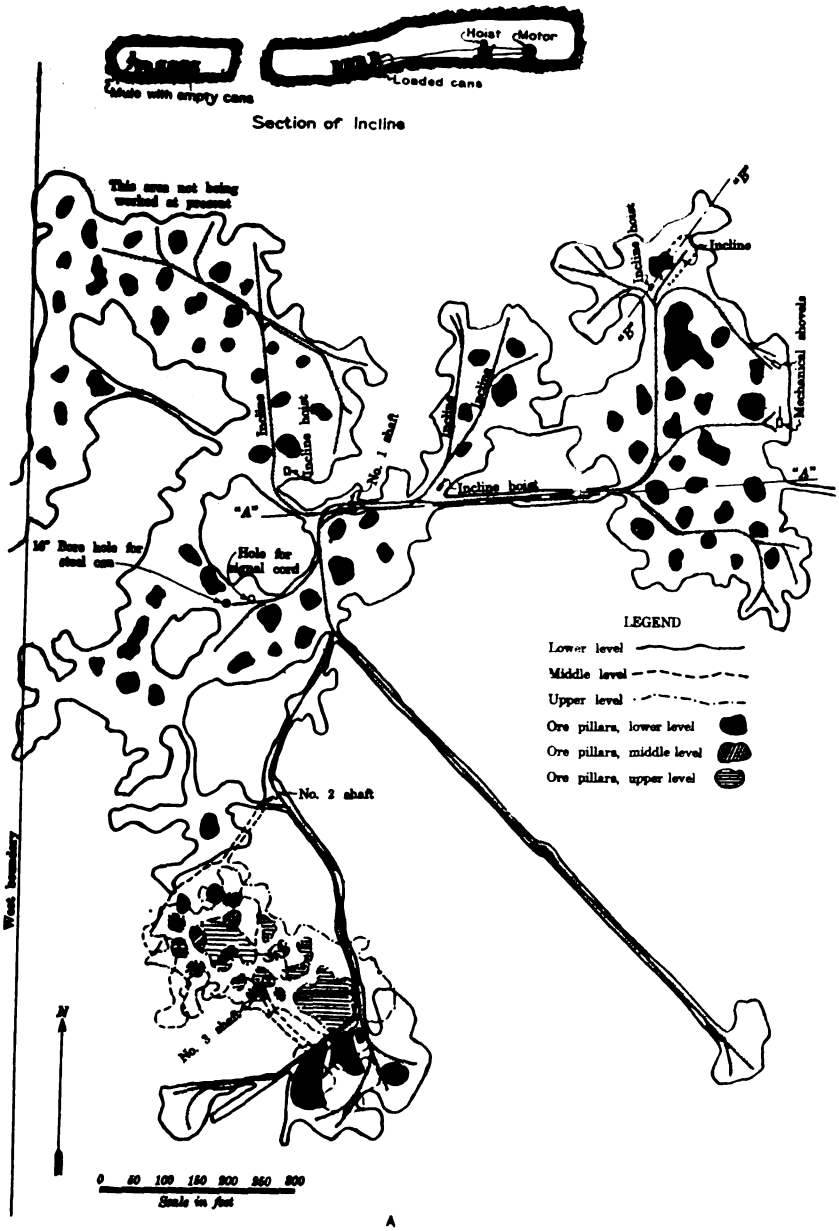

Figure 15.— A, Plan showing inclines at mine in the Tri-State district; B, winze method of reaching lower ore channels, Tri-State district

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of vapor which are caused by the exhaust and which often fog the drifts to such an extent that they interfere seriously with vision. Power costs will usually average about four times those for electric locomotives, and starting and speed control are better with electric locomotives.

Gasoline motors have been little used underground because of the danger from exhaust gases or of fire. They have been used occasionally, however, in open-stope mines where no timber is used and where the ventilation is exceptionally good. They have a field of usefulness in outside work around mines.

Charles E. Van Barneveld discusses locomotives for underground use in a comprehensive manner in "Mechanical Underground Loading in Metal Mines," published cooperatively by the United States Bureau of Mines and the School of Mines and Metallurgy, University of Missouri, in May, 1924. He gives considerable valuable data on types, sizes, capacities, and details of construction, operating costs, etc., which are not within the scope of the present paper.

Rope Haulage

The term "rope haulage" as employed in this paper does not refer to endless rope or main-and-tail rope haulage employed in some coal mines, particularly in foreign countries, but to auxiliary hoisting in underground slopes. Hoisting, as considered later under the caption "Hoisting" refers to hoisting through main hoisting shafts as distinct from auxiliary hoisting.

At Mineville, N. Y.,[24] auxiliary inclines are employed for hoisting and lowering ore in cars between intermediate and main haulage levels (fig. 14).

In the lead mines of southeast Missouri,[25] cars are hoisted from levels below the main haulage levels over slopes on inclinations up to about 30°. Some of these slopes have several levels connecting with ore bodies at different horizons. They are usually single-track slopes. On grades up to 4 per cent against the loads, trolley locomotives are employed.[26]

In the Tri-State zinc and lead district[27] there are many short, flat slopes driven below the main levels to mine ore in "runs" or valleys below the general floor of the deposits (fig. 15). Sometimes instead of employing slopes the bottom of the ore is reached through shallow winzes (fig. 15-a). In both slopes and winzes small air or electric hoists or the "tugger" type are usually employed to hoist the ore in "cans."

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24 Cummings, A. M., Work cited.

25 Jackson, C. F., Methods of Mining Disseminated Lead Ore at a Mine in the Southeast Missouri District. Information Circular 6170, Bureau of Mines, 1929, p. 8.

26 Poston, Roy H., Work cited.

27 Netzeband, Wm. F., Method and Cost of Mining Zinc and Lead at Mine No. 2, Tri-State District, Picher, Oklahoma. Information Circular 6121, Bureau of Mines, 1929, p. 8.
Banks, Leon M., Page 7 of work cited.
Keener, Oliver W., Method and Cost of Mining at Barr Mine, Tri-State Zinc and Lead District. Information Circular 6159, Bureau of Mines, 1929, 9 pp.

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At Mascot, Tenn.,[28] inclines are driven down the dip of the ore body, about 18°, to reach ore below the bottom of the vertical main hoisting shaft.

The slope head arrangement often requires careful planning, especially if large tonnages are to be handled. Since requirements of storage tracks for both empty and loaded cars, head room, and lateral space available, positions of existing drifts and crosscuts differ widely for different cases, slope-head layouts also vary. For large capacity, the back-switch head as used in some anthracite coal mines recommends itself for speed and minimum labor requirements. With this arrangement the hoistman raises the loaded cars past a switch which is automatic or may be thrown from the hoist platform and drops them back by gravity onto the loaded car track. The trip rider unhooks the rope and attaches it to the empty cars, then the hoistman raises them above the switch and lowers them in the slope.

Tracks

Table 3 gives some data on mine-track installation at a number of mines as described in Bureau of Mines information circulars and in other technical publications. While the data are incomplete and a relatively small number of mines are listed, they indicate in a general way the types of construction in common use over a much wider field.

The importance of well laid and maintained track has been emphasized often enough that it need not be stressed here.

For light locomotives and cars, 16 or 20 to 30 pound rails are used, 20 to 30 pound rail being preferred. For heavier work, 40 to 45 to 50 and 60 pound rails are commonly employed, and for long haulageways having a long life the heavier rails are amply justified for reducing maintenance costs, speeding up haulage, and eliminating derailments. Track gages are 18 to 36 inches, 18 inches being common for haulageways on which locomotives of the "trammer" type are in use and 24 or 30 inch gage widely employed for use with standard mine locomotives.

In ore mines ties are usually of wood, 4 by 6 inches, 6 by 6 inches, 6 by 8 inches, or 4 by 8 inches, are 18 to 24 inches longer than the gage of the track, and are spaced 24 to 30 inches apart. At some mines the ties are treated with wood preservatives, which undoubtedly increases their life under certain conditions.

Rails are usually connected with fish plates, which are of the angle-bar for the heavier weights of rail and flat plates for the lighter rails.

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28 Coy, Harley A., Mining Methods and Costs, American Zinc Co. of Tennessee, Mascot, Tenn. Information Circular 6239, Bureau of Mines, 1930, 11 pp.

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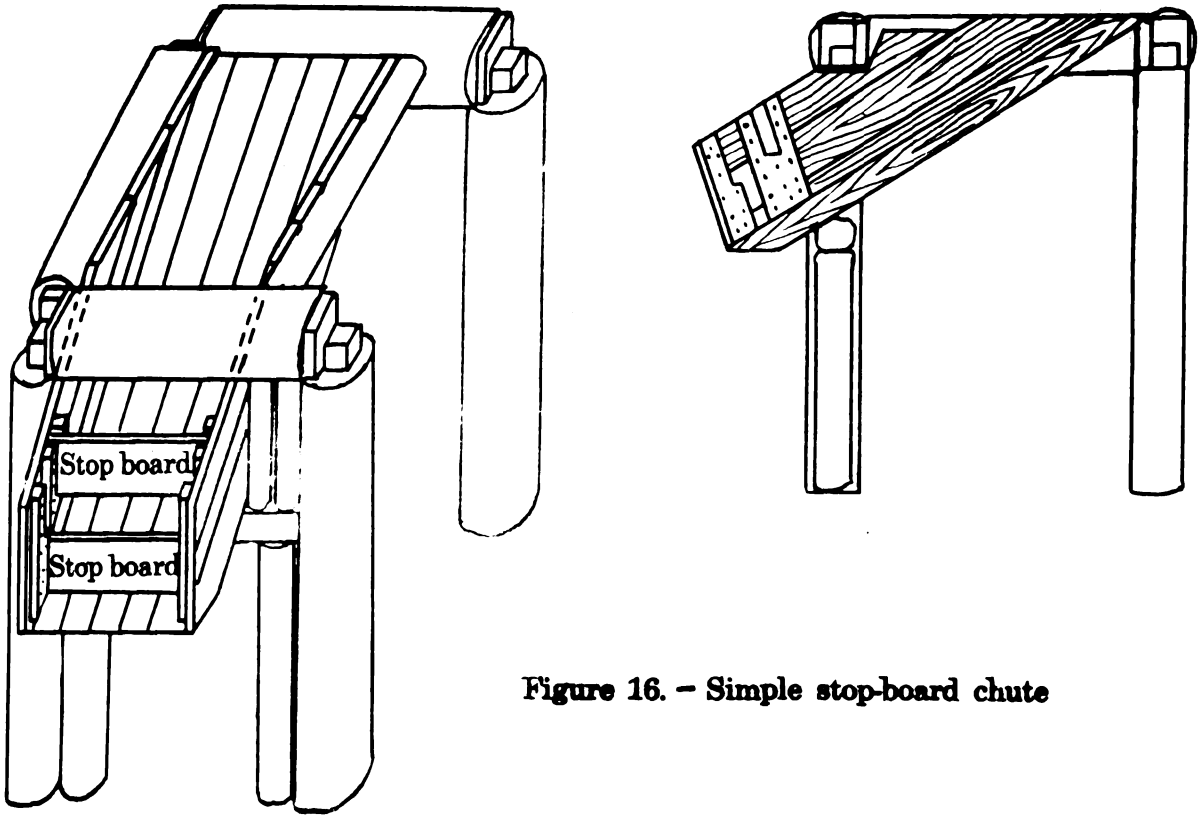

Figure 16. – Simple stop-board chute

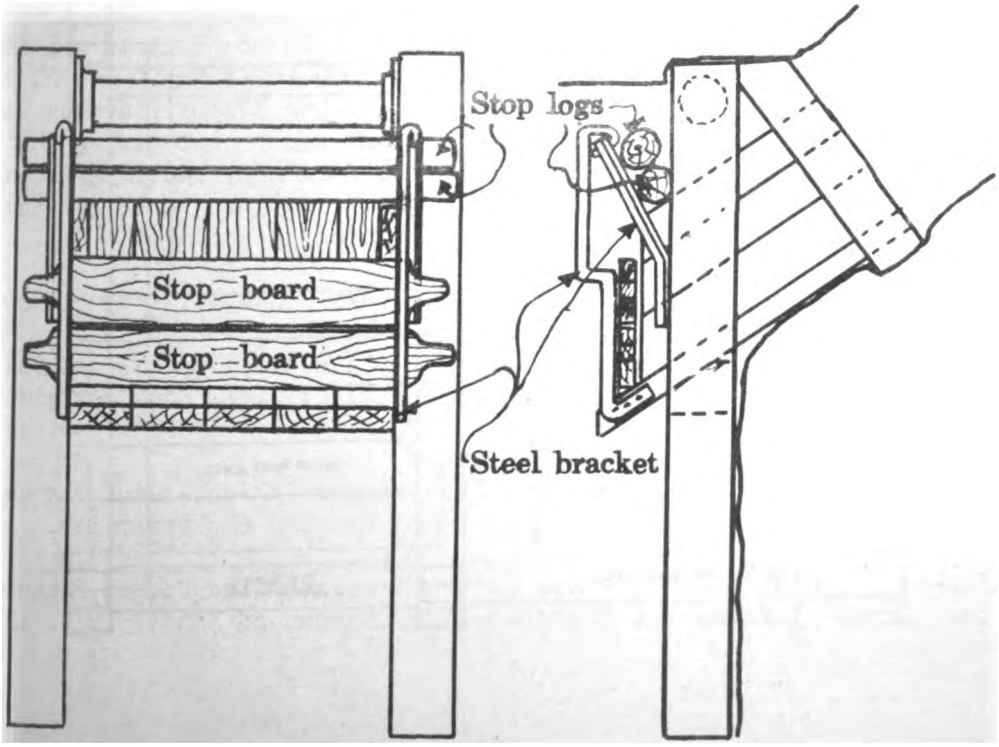

Figure 17. – Stop-board chute with steel brackets

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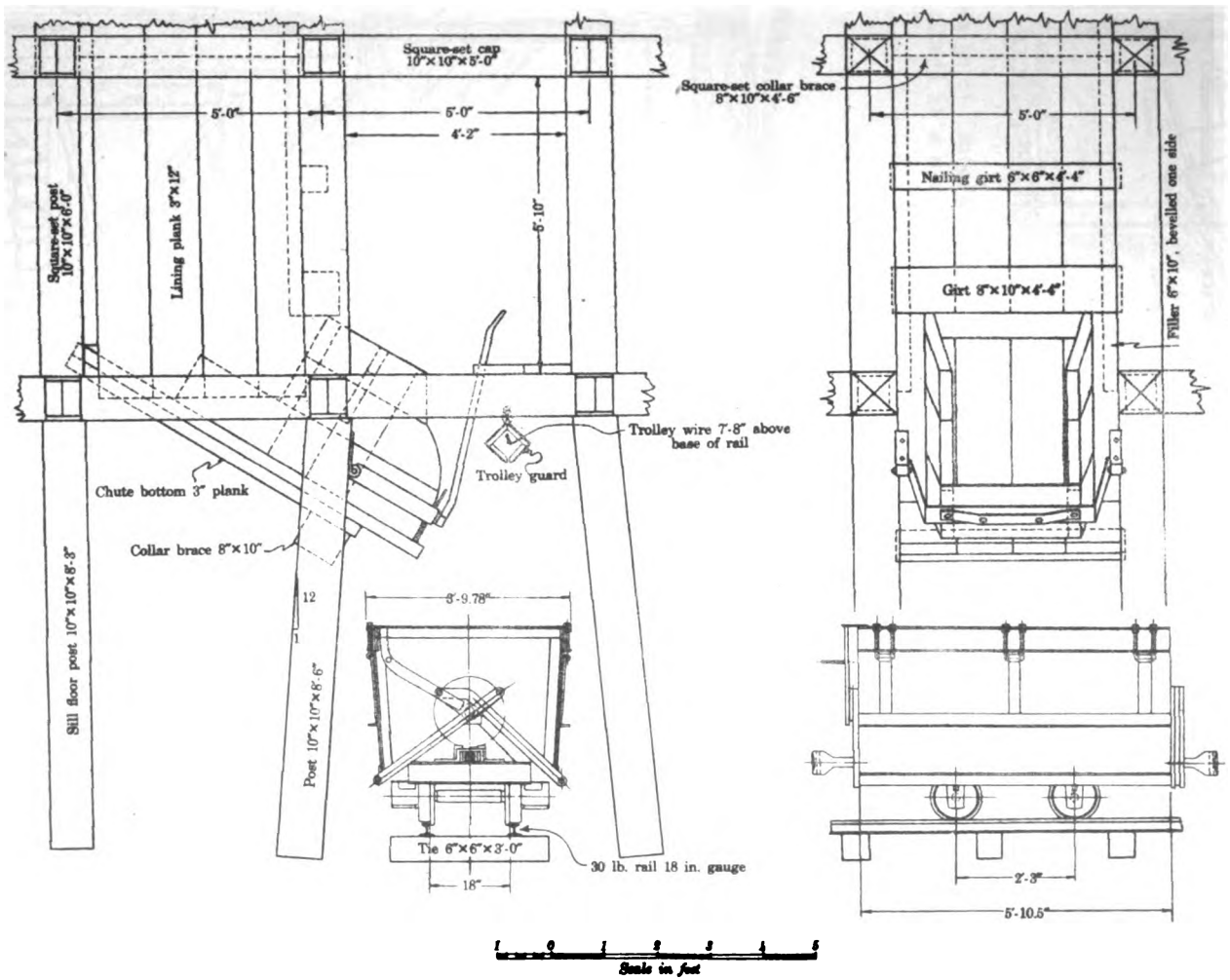

Figure 18.- Drift set, pony set, and chute with lip apron, loading gable-bottom car, Magma mine

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Figure 19.—Design of improved Alaska Treadwell finger chute used at a hard iron-ore mine

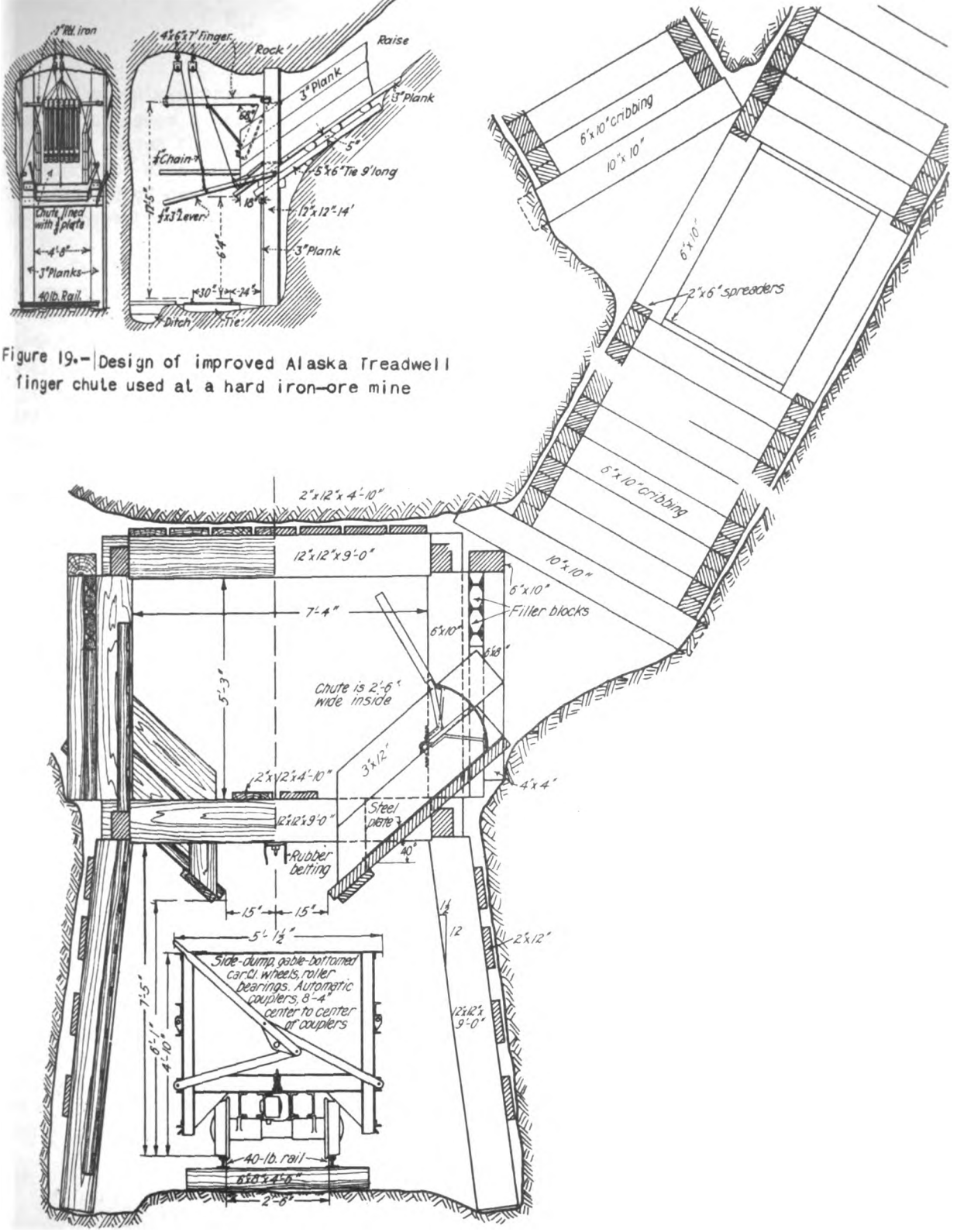

Figure 20.—Drift set, pony set, gable-bottom car, and overcut arc gate, Inspiration mine

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Loading from Chutes

The haulage crew often loads the cars when they are filled from chutes. In other instances a locomotive spots the empty cars at the chutes, in trains or singly, or leaves them on a siding near the loading chutes, and they are filled by loaders who also necessarily attend to the movement of cars for short distances. The operation of chute loading may therefore be properly considered as a part of the transportation system.

Various types of chutes are in use, and details of installation vary for the same type at different mines. The most common type is probably the simple stop-board gate chute (fig. 16), having one or two, and sometimes three stop boards for controlling the flow of ore. This type of chute is cheaply and quickly installed and serves the ordinary purposes of loading where the total tonnage to be passed through it is relatively small or where the rate of loading is small. The ore is drawn by raising the stop boards which are loosely held between cleats on the inner sides of the chutes, using a bar for this purpose. Instead of short chute boards fitting between the sides of the chute, longer boards are employed extending beyond the sides of the chute and resting against steel rails or bars (fig. 17). The projecting ends of the boards may be tapered to form handles so that, instead of using a bar, they may be raised and manipulated by hand. To prevent spillage of fine ore over the sides of the car after it has been filled, a light, narrow stop-board or apron which can be quickly set behind steel lugs on the lip of the chute is often used. A more elaborate arrangement for this purpose is a light, overcut, swinging, steel apron or toe board (fig. 18).

When handling soft, relatively fine muck, the types of chutes mentioned are well suited to the work, especially if the mining method requires a large number of closely spaced chutes.

In handling rougher and harder material with this type of chute, the boards wear rapidly or are broken by heavy chunks falling against them and have to be replaced frequently. Breakage of a board may result in burying a car and filling the drift under the chute. A very common type of chute and one which is not expensive is the "quarter-pan" or overcut, steel, arc-gate chute (fig. 20). This type of chute gate is rugged and is well adapted to handling hard, moderately rough muck where the width of the chute opening does not exceed 3½ to 4 feet. For greater widths, the pressure of the ore against the gate makes it difficult to operate by hand, and some sort of a mechanical contrivance, such as an air jack, is desirable. If it is installed so that the point of contact of the arc gate with the sloping bottom of the chute is slightly higher than the center of rotation, it will be found that the gate can be opened with less effort than where the contact is lower. When properly installed, rapid loading can be done with this type of gate. A light, removable toe-board below the gate can be used advantageously to stop fine material if a rock prevents closing the gate tightly.

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For handling blocky ore, especially where the amout of ore to be drawn during the life of the chute is large enough to warrant a more expensive installation, either the "finger" chute (fig. 19) or undercut arc gate (fig. 21) are well suited. For this type of material it is very desirable that chute openings be wide if rapidity and ease in loading are to be attained, a point which can not be overemphasized.

The finger gate was developed at the Alaska-Treadwell mine and has since been employed at many other mines, with and without much change in detail of construction. Figure 22 shows the gate as installed for operation by air jack at the United Verde Extension Mine.[29]

Figure 21 shows an installation at a hard iron-ore mine in Michigan where the gate is operated by hand through a system of levers, ropes, and pulleys.[30]

The object of this type of chute is of course to permit drawing a large block of rock without letting through a surge of material, by raising one or more fingers while the others are in the lowered position. This type of chute requires a lip apron or toe-board to hold back fine material which would otherwise run out between the fingers and overflow the car after it has been filled. This apron (fig. 22) is in the form of a small overcut arc gate while in figure 19 it is a flat steel plate which swings up when the fingers are raised and drops back in place by gravity when they are lowered.

The undercut arc gate is much favored by the writer because of considerable personal success with its use. Figure 21 shows a method of installing it for hand operation. Two men readily loaded 300 tons of blocky ore in three hours as an average performance. Figure 23 shows the same type of gate, air operated and combined with an air-operated check gate, used instead of a stop log check as in Figure 21. Such an installation is expensive and is only warranted where a large tonnage will be drawn from each chute.

Some operators favor an overcut vertical gate. A very simple application of this type for hand operation is shown in Figure 24. As a rule, however, this type of gate requires power operation, generally applied by means of an air or hydraulic cylinder (fig. 25). They are not as well adapted to blocky material as the undercut type of arc gate or the vertical undercut gate.

The "Chinaman" chute is still used at some mines. This is simply an opening in the lagging over the back of the drift through which the ore is shoveled or scraped into cars. Figure 26 shows an adaptation of the Chinaman chute with a grizzly chamber above as employed at Ducktown, Tenn. This arrangement affords an opportunity to break up chunks of ore too large to be handled in the cars. The chunks can be pulled aside during actual loading without the delays often occasioned when "working" blocky ore through regular chutes. At Ducktown the grizzly men also spot and load the cars.

29 D'Arcy, Richard L., Work cited.

30 Eaton, Lucien, Method and Cost of Mining Hard Specular Hematite on the Marquette Range, Michigan. Information Circular 6138, Bureau of Mines, 1929, p. 11.

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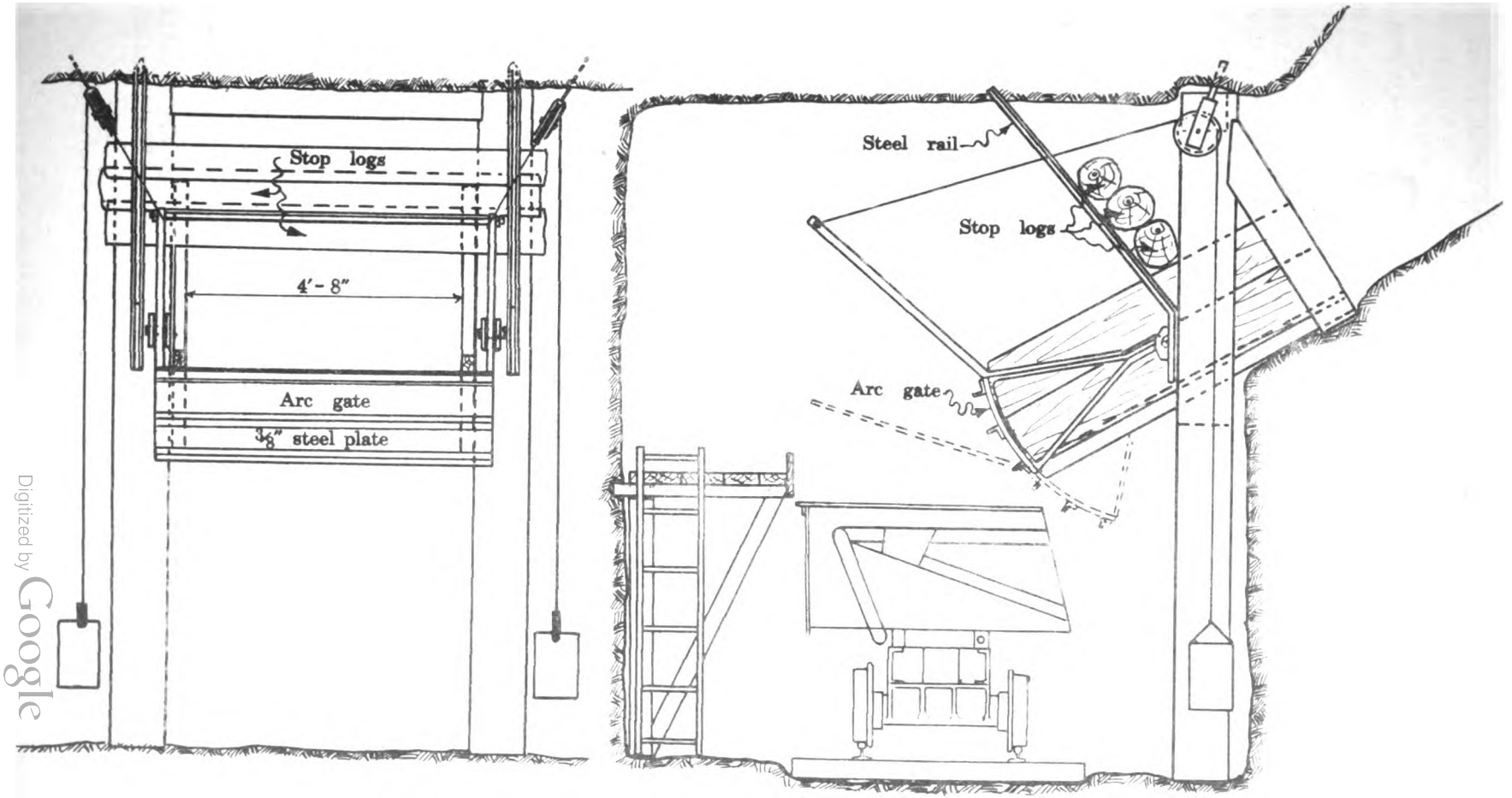

Figure 21. – Hand-operated, counterweighted underslung arc gate

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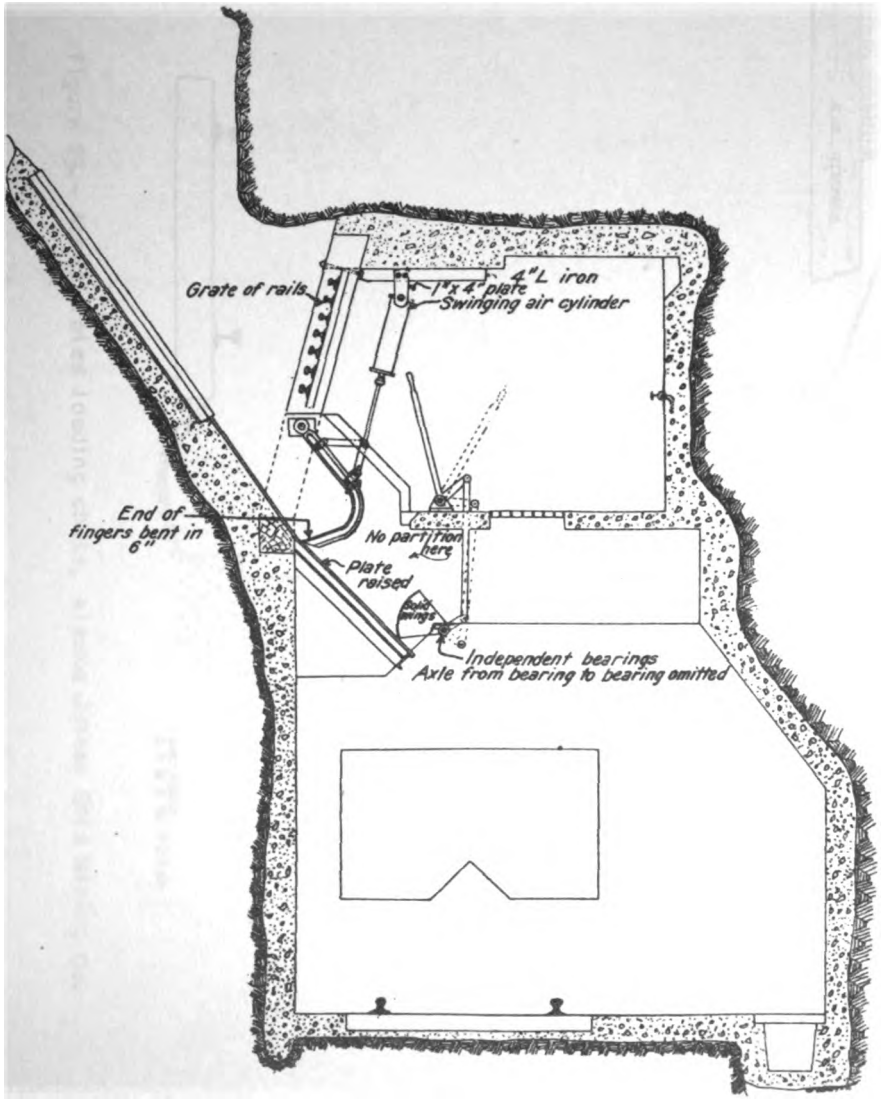

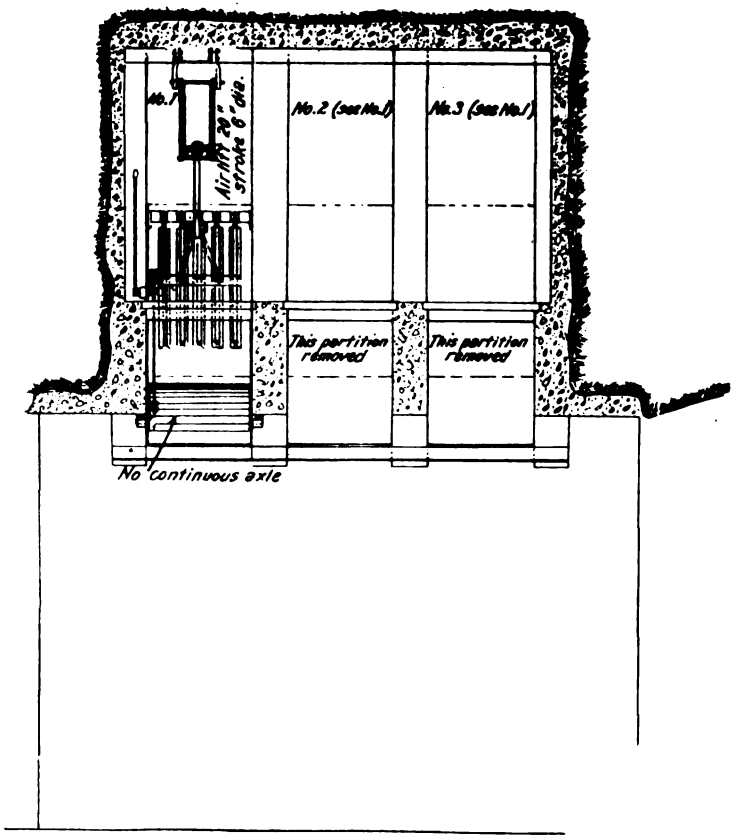

Figure 22.– Loading gates, main ore pocket, United Verde Extension mine

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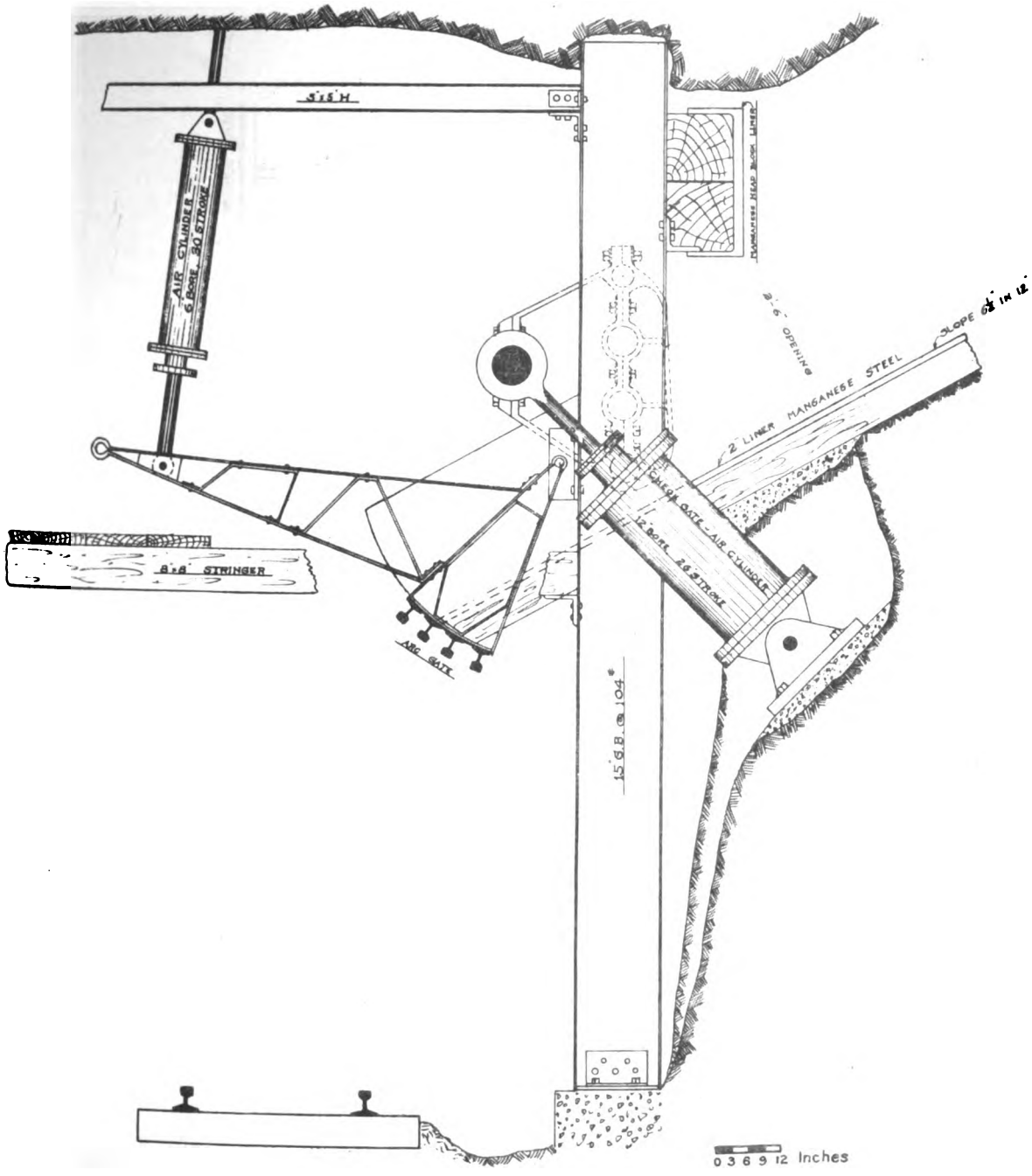

Figure 23.- Air-operated loading chute, Alaska Juneau Gold Mining Co.

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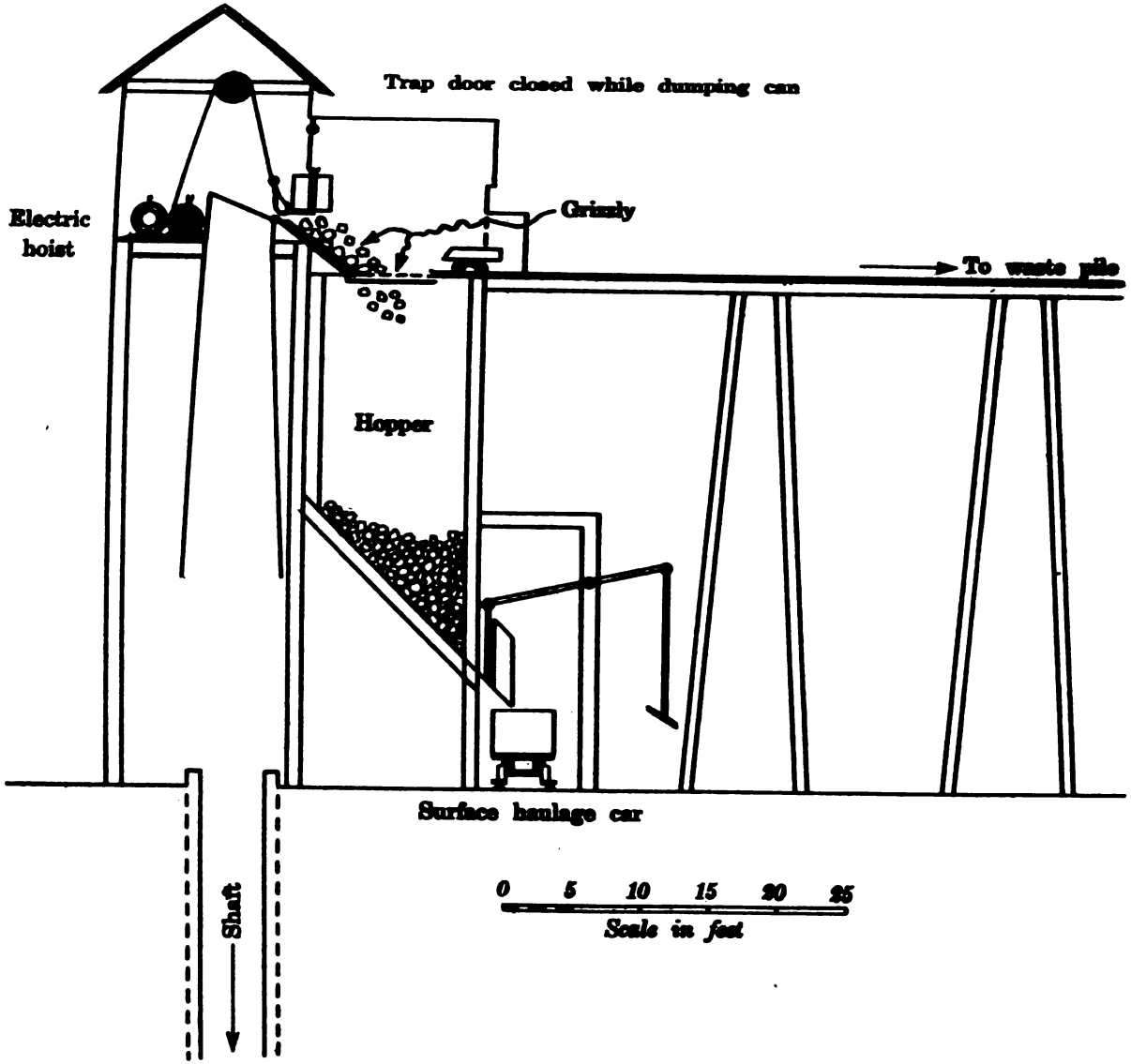

Figure 24.- Hand-operated vertical overcut gate

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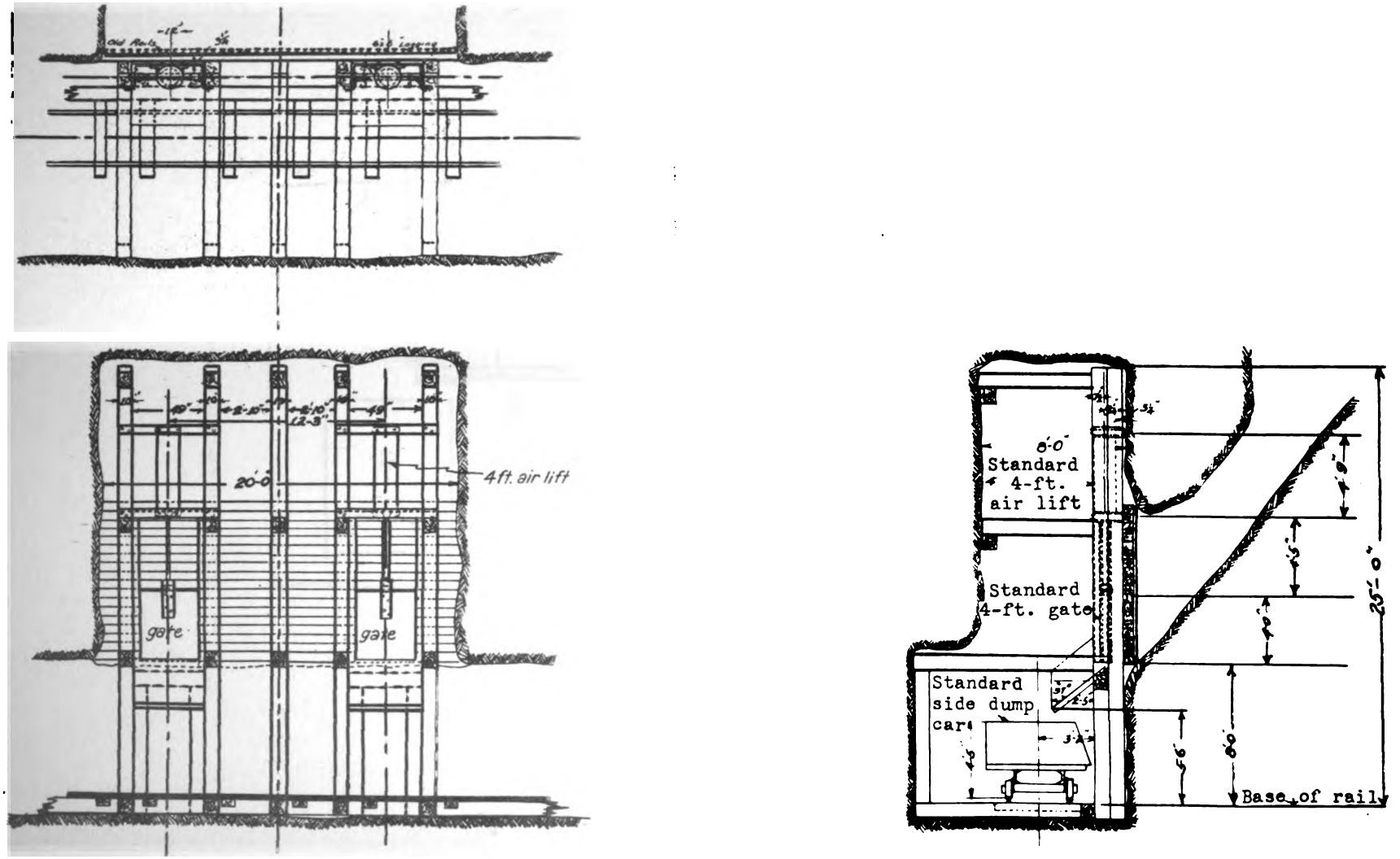

Figure 25.- Standard front for underground ore pocket, Mineville, N. Y., showing vertical air-operated gate

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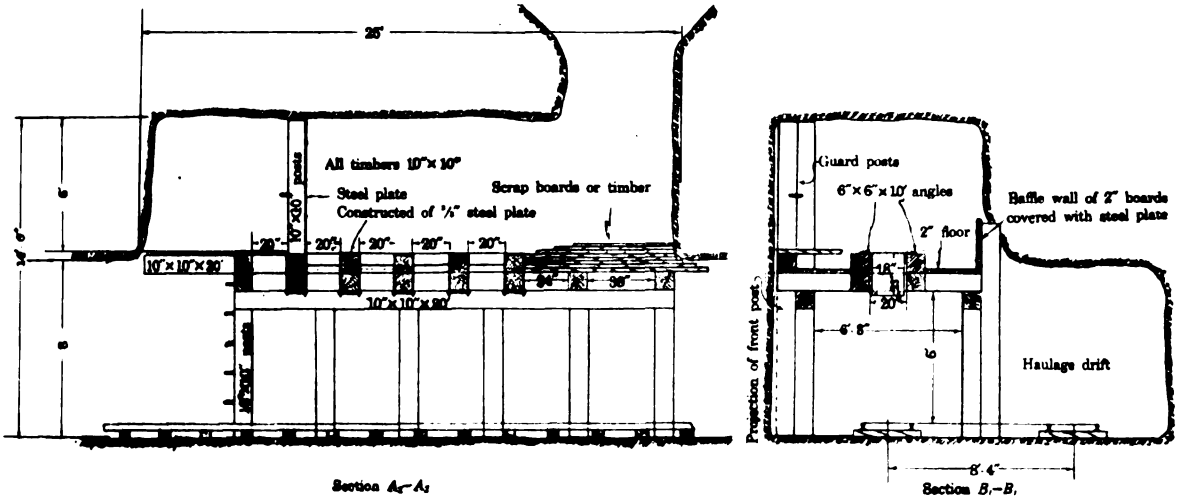

Figure 26.- "Chinaman" chutes and grizzly chamber

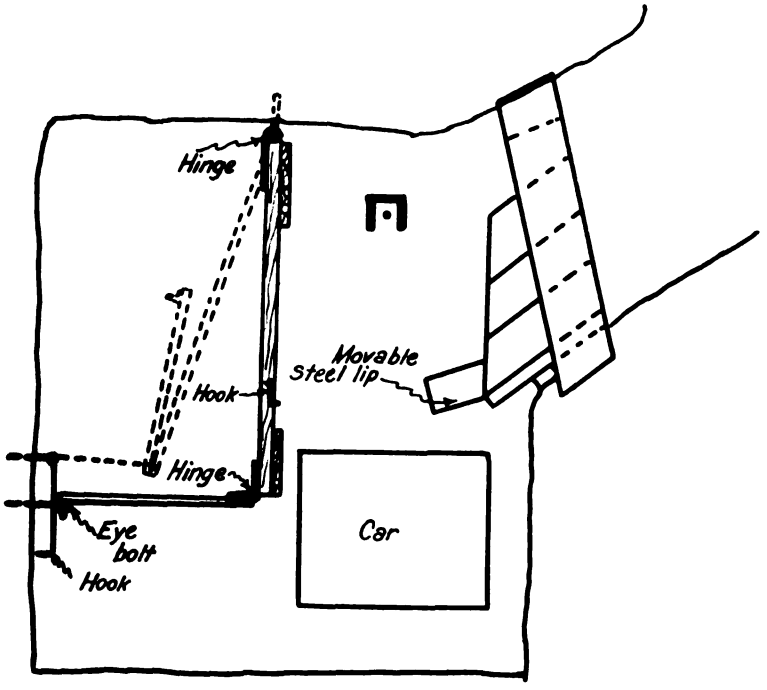

Figure 27.- Movable platform for loading from chutes

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Grizzlies are more often installed at some distance above the level with a storage raise for ore which has been blocked through the grizzly between it and a standard loading chute at the haulage level. In handling ore which requires blockholing or sledging, the provision of grizzly chambers reduces delays in loading since the size of the grizzly opening limits the size of material which the chute will have to handle. The chute can be designed accordingly.

The loading chute is a point at which accidents are common, and should be designed with this fact in mind. Accidents to fingers and hands are common, and foot or leg injuries caused by large chunks rolling off the car are of by no means rare occurrences. To overcome the latter type of accidents many operators construct platforms on which the chute pullers stand above the level of the lip of the chute (figs. 21 and 23), or, as is common particularly in the southwestern States, pony sets (figs. 18 and 20) are erected over the regular drift sets at each chute. The latter is probably the safest method that can be devised, as it not only places the chute puller above the chute lip but above and in the clear of trolley wires. A loading platform such as that shown in Figure 21 introduces a certain hazard in movement of trains as it reduces the clearance between the cars and lip of the chute. At the Homestake mine in South Dakota a swinging platform which is hooked back out of the way when not in use and which is very quickly and easily put in place again for loading, eliminates this hazard (fig. 27). The illustration also shows the movable lip which is swung back out of the way when loading is finished.

Good illumination at each chute should always be provided.

Conditions, then, determine the type of chute to be employed. The governing factors are: Nature of material handled, rate of loading required (rapid loading is naturally always desirable), total tonnage to be handled through the chute during its life, size of cars, safety in operation, cost of installation and of maintenance.

Sometimes when the drift is in very heavy ground the type of chute used will be influenced by this fact.

Use of Scrapers

As previously stated, scrapers serve the dual purpose of loading and conveying equipment, and therefore they deserve brief mention in this paper. Scrapers are used in ore mines (1) for loading cars near the face in stopes, drifts, tunnels and crosscuts; (2) for intermediate transport of ore from the stope face to mine cars or to chute raises; (3) for transfer of ore on sublevels from the bottoms of a set of raises to the top of a chute raise; (4) and for spreading filling in cut-and-fill stopes.

(1) When used in development headings the scraper serves primarily as a loading machine and to a negligible extent for transport. When loading from the face in stopes where the cars are run along or up to the working face, the scraper functions in the same manner.

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(2) When employed to drag ore from the face of a flat stope to cars on a haulage level or to chutes, the scraper functions as a conveying machine as much as it does for a loading machine.

At Mineville, N. Y.,[31] scrapers are employed to drag the broken ore in flat stopes from the face to cars on intermediate levels (fig. 28). The scraper dumps its load into a flat chute whence it is drawn off by gravity into the cars. Here the scraper drags the ore for distances up to 150 or 200 feet. The ore breaks in large chunks, and heavy scrapers of the hoe type, operated by double-drum, 25-hp., electric hoists are required to handle this material.

At a hard-ore mine in Michigan, hoe-type scrapers are used in open stopes where the dip is flat to drag the ore to chutes put up from the haulage levels[32] and directly to cars placed under a slide. The scrapers are 48 inches wide, 7 feet long, and weigh 1,500 pounds. They are drawn by double-drum, 25-hp., electric hoists using 5/8-inch extra-plow-steel rope. A complete scraping outfit, exclusive of electric cable, costs $1,150 set up in place.

At Birmingham, Ala., scrapers are used extensively for transferring and loading ore from the room-and-pillar stopes into cars standing on the haulage level. The dip of the ore varies from nearly horizontal up to 25 or 30° and averages about 15°. The ore bed will average around 8 or 10 feet in thickness. The haulage levels are turned off from the main slope at intervals of about 200 feet, and the rooms are worked up the dip from one level to the next. The maximum scraping distance is thus about 200 feet. In development work scrapers weighing about 750 pounds are used for loading cars placed under a slide. For handling ore in stopes large scrapers weighing 2,700 to 3,100 pounds equipped with teeth and drawn by 50-hp. electric hoists are employed. The scraper hoists are mounted on self-propelling trucks which run on a separate track paralleling the haulage track in the wide entry, the haulage track being between the stope and the hoist track. The large size of the equipment here is occasioned by the fact that the ore breaks in large slabs and the toothed scraper is required to secure a hold under these slabs. The scrapers deliver their load into 5-ton, solid-body cars which are later dumped in a rotary dump. Two men of the total force in a stope crew are assignable to scraper operation and a third to operating the haulage motor which spots the car at the scraper slide. Since the scraper loads an average of 250 to 300 long tons per shift, the labor charge for scraping and loading can be figured on the basis of 125 to 150 tons per shift, or 0.08 to 0.067 man-hours per ton (10 hour shift). The record is something over 600 tons in 6 hours. At this operation the use of scrapers has replaced the former practice of laying tracks diagonally up the dip and running cars over stiff grades to the face and has become quite distinctly a part of the transport system.

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31 Cummings, A. M., Page 8 and Figure 8 of work cited.
32 Eaton, Lucien, Pages 9 and 10, and figure 6 of work cited.

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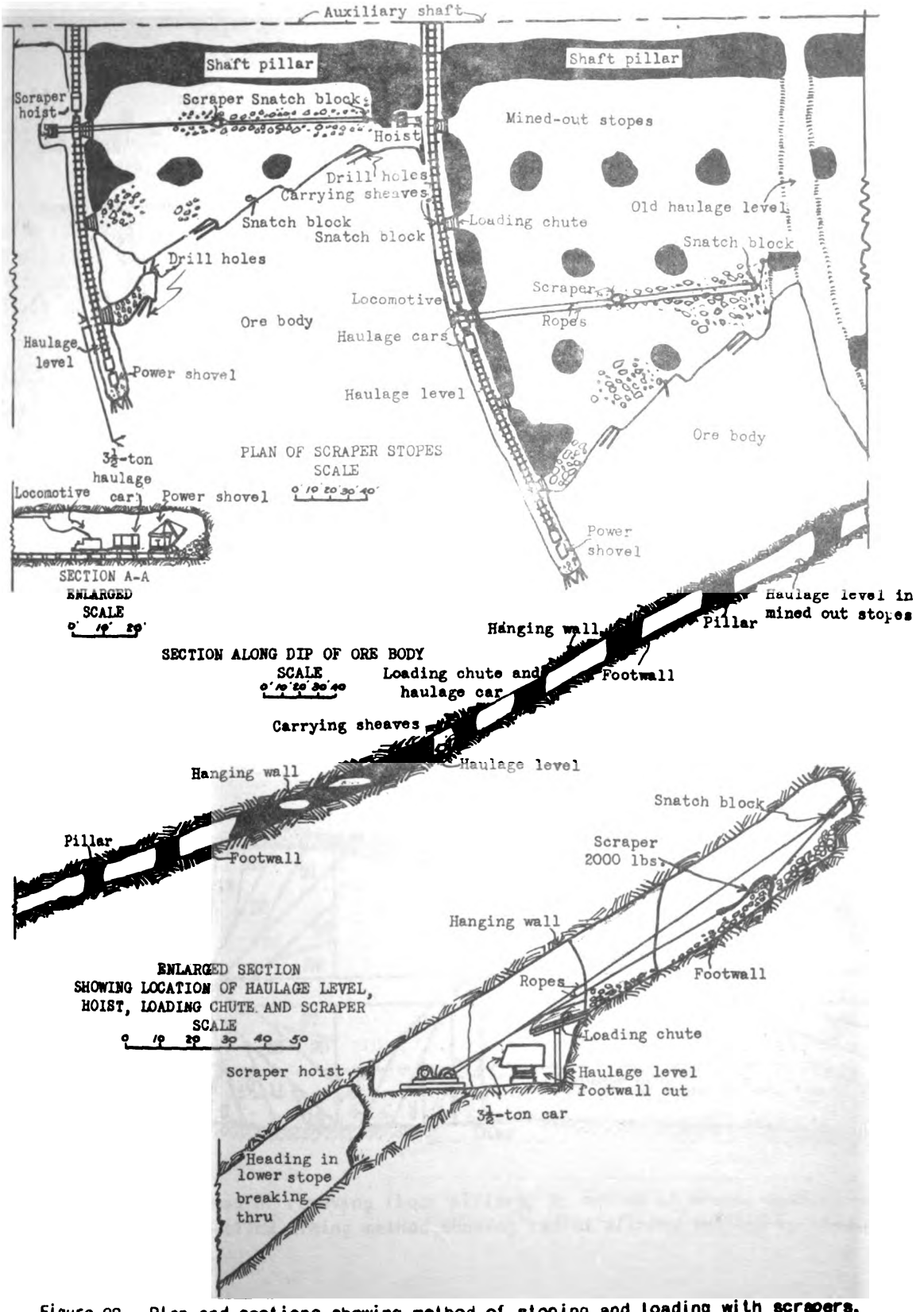

Figure 28.- Plan and sections showing method of stoping and loading with scrapers, Mineville district

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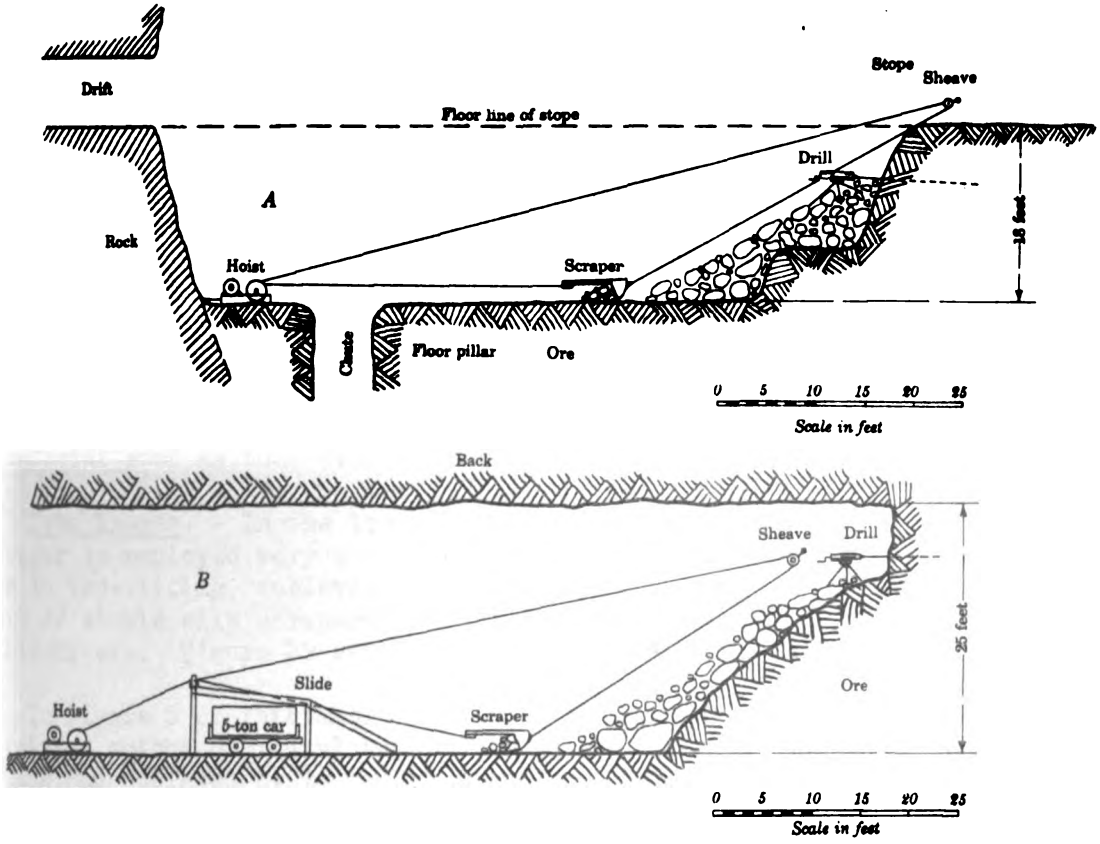

Figure 29.- A, Method of removing floor pillars; B, method of breast stoping using scrapers; C, top-slice mining method showing radial slicing adapted to scraper loading

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In the Lake Superior copper district scrapers are employed extensively both as loading and as conveying machines. They are used both for scraping the ore down flat dips from the face to cars on the level,[33] and for picking up ore which runs by gravity from the stope face onto the floor of the level and for conveying it along the drift to a loading slide and discharging it into cars there.[34] Scrapers of the open hoe type, usually without teeth and weighing 600 pounds and more, are used in stopes. For conveying on levels, as mentioned, the scrapers weigh about 1,500 pounds, have a steep digging angle, and average about 100 tons per shift.

At Mascot, Tenn.,[35] scrapers are employed in open stopes for dragging the ore on flat dips to the tops of the chute raises. The open hoe-type scraper is employed using 10 to 15 hp. electric hoists for clean-up work and 25 hp. hoists for heavier work. Recently a two-speed scraper hoist has been installed, the lower speed being employed for picking up the load and then shifting to the higher speed for transporting it. This feature is particularly desirable for handling rough material such as that at Mascot.

Iron Ranges. - In the iron-ore mines of Minnesota, Michigan, and Wisconsin, the scraper is employed very extensively both as a loading and as a conveying machine in top-slicing, sublevel caving, and open-stope operations. Box-type scrapers or simple slip scrapers are used in soft ore and hoe-type scrapers in hard, blocky ore. Figure 29 shows scraper operation in a hard iron-ore mine.

In Figure 5 of Information Circular 6179 Lucien Eaton describes and illustrates a method of radial top slicing in which hoe-type scrapers weighing 325 pounds and operated by 7½ or 10 hp. electric hoists are employed to drag the ore from the face for distances up to 75 feet into chute raises. In this system the old method of loading by hand into cars which were trammed to the chutes has been superseded, and loading and tramming are performed by the scrapers, eliminating tracks and cars from the sublevels (fig. 29a). This method is very commonly employed in the Lake Superior region.

In pitching ore bodies, such as are encountered in some of the Michigan iron-ore mines, the scraper is used on transfer sublevels to transport the ore from a series of ore raises to a chute driven up from the haulage level. These sublevel raises are simply open raises without chutes. The ore from the stopes above is scraped into the tops of these raises and falls directly to the floor of

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33 Van Barneveld, Charles E., Mechanical Underground Loading in Metal Mines. Published by the University of Missouri as a cooperative work between the U. S. Bureau of Mines, Mississippi Valley Station and the Missouri School of Mines and Metallurgy, May, 1924. Fig. 141-top, figs. 144, 145, pages 344 and 345, and text pages 339 and 347.

34 Van Barnelveld, Charles E., Word cited, fig. 140, p. 330, and text pages 326 to 337.
Crane, W. R., Mining Methods and Practice in the Michigan Copper Mines. Bull. 306, Bureau of Mines, 1929, fig. 123.

35 Coy, Harley A., Page 6 of work cited.

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the subdrift where it piles up. From these piles the ore is dragged along the subdrift by large scrapers to the top of the main-level chute raise. By this system the driving of a series of raises in waste from the main level to the bottom of the portion of the pitching ore trough which lies above the haulage level is eliminated, and the sublevel and raise development are all in ore. The amount of main level development in rock is also decreased.[36]

At one iron ore operation with which the writer is familiar, large scrapers are employed in a similar manner on the main haulage level in an ore body about 150 feet wide. The main haulageway from the shaft is driven in the footwall, and from this haulageway crosscuts are driven across the ore body at intervals of about 300 feet. These constitute the main haulageways of the level. The haulage crosscuts are then connected by longitudinal scraper drifts driven at an elevation 4 feet above that of the rails in the haulage drifts. From these longitudinal or scraper drifts, raises are put up to the top of the ore at 34-foot intervals. From the tops of these raises, sublevel caving is started. The ore from the sublevels is dragged to the raises and falls down into the scraper drifts where it piles up. The bottom of the scraper drift is covered with plank on which are laid closely spaced rails to make a smooth bottom for scrapers to slide on. Scrapers 5 feet wide are employed to drag the ore from the piles to the haulageway where they discharge the ore over steel cantilever slides into the regular 40 cubic foot rocker-dump cars.

This system was devised for two purposes. Much of the ore was sticky and gave a good deal of trouble by packing in chutes, and the new system eliminated this trouble by eliminating the chutes. Also, as the mining which starts at the top progresses downward, the ore raises become shorter, and their capacity was greatly lessened under the old chute method. Due to this fact, the contractors in the stopes were often delayed by full chutes and had to wait for the motor crew to draw their ore. The additional capacity for broken ore in the scraper drift largely eliminated this difficulty. Also, owing to the fact that a large quantity of ore was available in one scraper drift, tramming efficiency was doubled since the trammers could fill a whole train at one place and did not have to go from chute to chute for a few cars at a time from each one.

Waste Filling. - The spreading of waste for filling in the stope has frequently been done by scrapers and has proved very successful in many places, including some of the gold mines in Ontario recently visited by the author of the present paper. At the Morning Mine in Idaho,[37] scrapers are employed for removing waste from waste crosscuts and conveying it to the stope. At Cam[illegible], scrapers are used for moving ore and spreading waste fill in cut-and-fill stopes.[38]

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36 Graff, W. W., Mining Congress Journal, October, 1929.

37 Wethered, C. E., and Coady, Leo J., Mining Methods at the Morning Mine of the Federal Mining and Smelting Co., Mullan, Idaho. Information Circular 6238, Bureau of Mines, 1930, p. 8.

38 Catron, William, Work cited.

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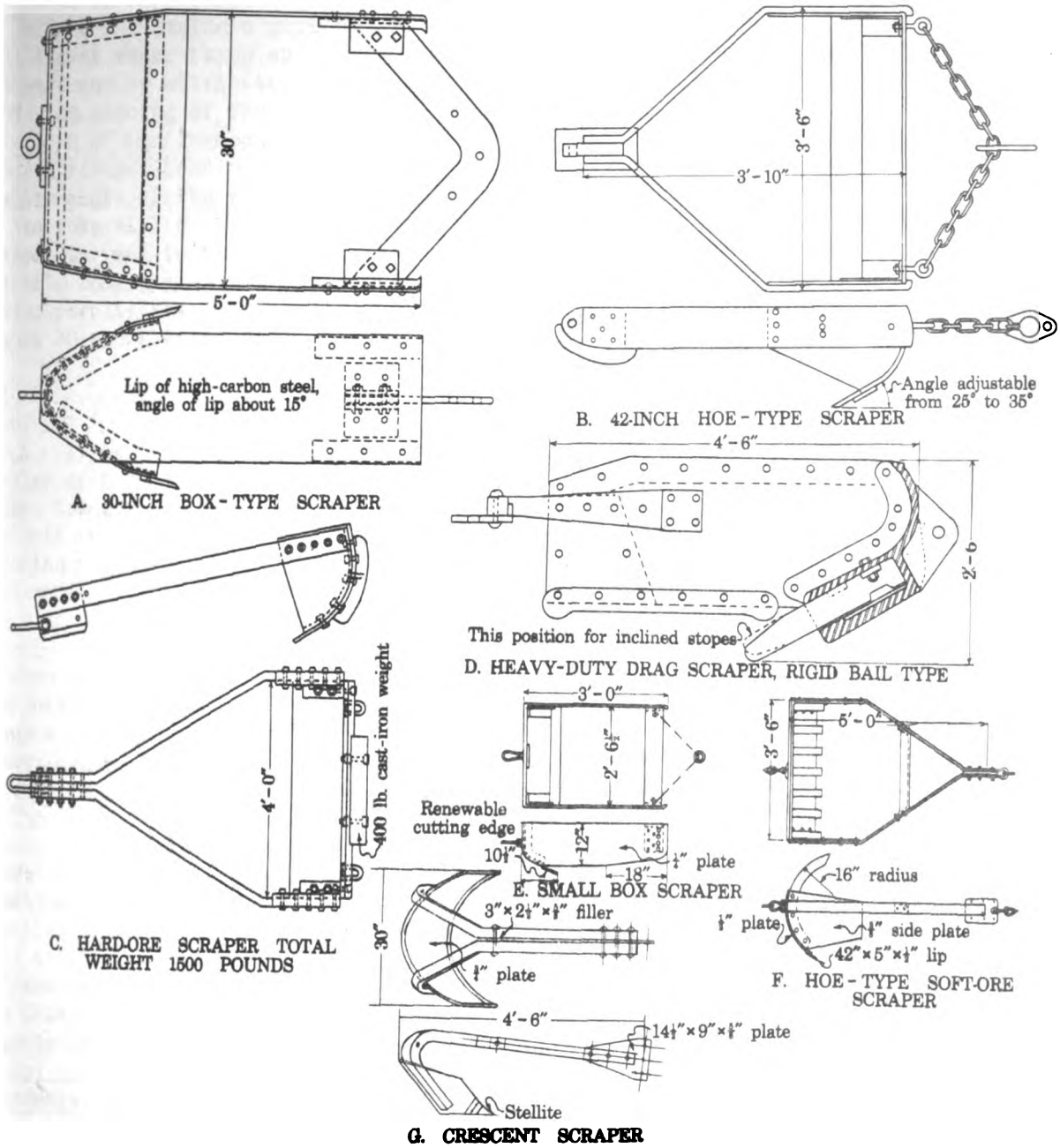

Figure 30. – Common types of drag scrapers for underground use

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Speaking of scraper work in general, it may be remarked that its success at any operation will depend upon applying it under conditions to which it is suited; employing the type, size, and weight of scraper best adapted to the character of material; use of a scraper hoist having sufficient power for the work to be done and having a rope speed suited to the particular digging conditions; intelligent supervision and training of the operators. Many early failures with scrapers can be attributed to too light equipment and hoists of insufficient power or to the placing of the work while still in the experimental stage under the direction of men inadequately equipped for experimental work or predisposed against scraper loading. Sometimes a difference of but a few degrees in the digging angle of the scraper blade or teeth or a slight difference in the sweep of the yoke will determine the success or failure of a scraper. At one mine a scraper is used in which the teeth are of two different lengths, the blade being set with long and short teeth alternately. This combination was said to give much better results than where either the long teeth or the short teeth were used alone. Figure 30 shows details of several types of scrapers used in underground work.

HOISTING

It is not within the scope of this paper to attempt a comprehensive discussion of hoisting problems, calculations of hoist capacities and power requirements, details of hoist, skip, cage, and headframe construction, etc., but hoisting will be briefly reviewed as a part of the underground transport system in its relation to other departments of underground operation as brought out in the series of information circulars thus far published by the Bureau of Mines and dealing with mining methods and practice.

Although some producing ore mines in the United States use inclined shafts for hoisting ore, the vast majority employ vertical shafts for this purpose. Notable exceptions are some of the copper mines of Michigan,[39] the iron mines at Mineville, N. Y.,[40] the iron mines in the Birmingham, Ala., district,[41] and the Burra-Burra mine, Ducktown, Tenn.[42]

For prospecting and developing a flat dipping deposit which has not been proved at depth, an incline shaft has decidedly obvious advantages. An incline shaft usually follows the dip of the ore body closely and, although the length required to reach a given depth is greater than for a vertical shaft, long crosscuts are not required to connect it with the ore body, thus saving expense and time in development. For preliminary prospecting, an incline shaft in the vein serves the double purpose of staying with the ore, avoiding blind prospecting, and securing development at minimum expense.

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39 Crane, W. R., Work cited.

40 Cummings, A. M., Work cited.

41 Crane, W. R., Iron Ore (Hematite) Mining Practice in the Birmingham District, Alabama, Bull. 239, Bureau of Mines, 1926, 143 pp.

42 McNaughton, C. H., Work cited.

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Frequently after extensive deposits have been proved by development from incline shafts, vertical shafts are sunk for most economical operation during the productive life of the mine. Incline shafts in or near the ore body are often disturbed by movement and subsidence caused by adjacent mining operations, whereas a vertical shaft in the footwall is not usually affected thereby unless some unusual fault condition exists.

Some large and deep mines developed by incline shafts are probably still using these shafts for operating purposes because production is at such great depths that the cost of new vertical shafts from the surface is not warranted in the light of the probable remaining profitable life of the mines.

In the Michigan copper district[43] several deep vertical shafts were sunk in the hanging wall to develop the conglomerate lode at considerable distance from the outcrop, the upper part having been developed and worked through inclines. The Red Jacket shaft is a vertical shaft which was sunk after years of development and production through incline shafts, as a protection against loss of territory by fires in heavily timbered stopes.

At Mineville, N. Y., incline shafts are sunk in or just under the ore in flat-dipping measures and are used for hoisting to the upper levels whence the ore is taken to surface through vertical shafts.[44]

At Mascot, Tenn., the flat-lying ore bed is developed by a vertical shaft to a depth of 560 feet. From this level inclines are driven up and down the pitch of the ore body, and the ore from the other levels is transferred to the main shaft level, dumped into the skip pocket at the vertical shaft, and from there is hoisted to surface.

At the Burra-Burra mine[45] the original ore-hoisting shaft was an incline shaft on a 70° slope. Later a vertical shaft was sunk at some distance from the other and was first used for handling supplies but will eventually be the main ore-hoisting shaft.

Ore is usually hoisted in cars on inclines up to a maximum of 30 to 35°, but on steeper dips skips are employed, as a rule.

In vertical shafts it is customary and often obligatory by law to provide safety dogs on all cages and skips. The writer has not seen any device to effect the same purpose in incline shafts, yet if the rope breaks the results would be just as disastrous in an incline shaft as in a vertical shaft without these protective devices.

Another objectionable feature of the incline shaft is that the wear on the hoisting rope is greater than in vertical shafts, even though idlers are provided.

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43 Crane, W. R., Bull. 306, cited.
44 Cummings, A. M., Work cited.
45 McNaughton, C. H., Work cited.

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The simplest hoisting practice in vertical shafts is illustrated by the method usually employed in the Tri-State zinc and lead district. Here individual mines are usually small, the unit of area being a 40-acre tract; the ore is near the surface, the depth of the shafts rarely exceeding 300 feet.

In this district shafts are usually 5 by 7 feet, having but one compartment, and are untimbered except through surface material, shale, or badly fractured ground. Electrically operated 75 to 125 hp. hoists, usually mounted on the headframe or "derrick" directly over one side of the shaft, are employed for hoisting the ore in "cans" of about 1,300 to 1,400 pounds capacity.[46] These cans are ordinary sinking buckets with a ring in the bottom. No cross-heads and guides are used in the shaft, and the cans are hoisted on a 5-inch nonspinning cable. The hoistman, standing alongside the shaft opening in the derrick, raises the can above the apron level, attaches the dumping hook to the ring on the bottom of the can, at the same time lowering the dumping apron into position over the shaft opening, and then dumps the can by lowering it with the hoist (fig. 24). The operation is completed with surprising rapidity, and the bucket is raised, unhooked, and lowered back into the shaft with equal speed. When hoisting starts and as long as there is a supply of loaded cans at the bottom, hoisting is continued without any signals between the hoistman and the "hooker" who attaches and detaches the cans at the bottom of the shaft. With a steady supply of ore and good teamwork between the hooker and hoistman it is not uncommon to hoist 400 to 500 cans per shift. Hoisting is usually from the bottom of the shaft only, but a few mines have intermediate levels - generally not more than one, however.

The cans are brought to the hooker's platform on low, flat trucks (fig. 3), the tops of which are level with the platform. The hooker attaches the hoist rope and the hoistman raises the can immediately, being assured that the can has been attached by the "feel" of the rope. While the loaded can is being hoisted, the hooker rolls the empty can onto the empty truck, and by the time the next empty is returned, the "bumper" man has removed the empty can and placed a loaded can on its truck alongside the platform.

For small production, 300 to 350 tons per day, this practice requires a minimum investment for hoisting equipment and could perhaps be employed advantageously in other districts for development to shallow depths and up to the time when output, depth, and ore reserves warrant more expensive installations; thus it would help to conserve capital during the early life of the mine when it is often so badly needed.

Some of the newer shafts on larger properties in the Tri-State district have been equipped with skips[47] operating in balance, and one at least has with self-dumping cages.[48] One company has recently opened up a large tract with a shaft equipped with standard type of steel headframe and self-dumping skips in balance and is opening several others with similar equipment.

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46 Banks, Leon M., Page 5 of work cited.

47 Wetzeband, Wm. F., Method and Cost of Mining Zinc and Lead at No. 1 Mine, Tri-State Zinc and Lead District, Picher, Oklahoma. Information Circular 6113, Bureau of Mines, 1929, 11 pp.

48 Keener, Oliver W., Information Circular 6159, cited.

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Most ore mines in the United States now employ skips for hoisting ore. Some employ skips for both ore and waste, others use skips for the ore and hoist waste in cars on cages, and yet others use cages for all hoisting.

Under ordinary conditions, skip-hoisting from underground shaft pockets is the most economical method. Circumstances may exist, however, which make cage-hoisting desirable. One mine visited recently which is being developed for large production and is now hoisting about 2,000 tons per day, is being equipped for cage-hoisting. At this property the determining factor was that several classes of material - direct smelting ore, concentrating ore, siliceous flux, and waste - must all be hoisted separately. Separate pockets for each class of material on every level (levels are 125 ft. apart) would be expensive to install and maintain and would require large openings around the shaft. These objections could be partly overcome, however, by a system of ore passes between levels such that hoisting would only be from one, two, or three levels. At this mine automatic car stops and caging devices similar to those employed in large coal mines are used to eliminate part of the caging labor usually required where cage-hoisting is practiced.

Large cars are desirable for mines having a high rate of output, as previously pointed out. Large cars require large cages for hoisting ore, and these, in turn, require large shafts. Thus for large output, minimum size of shaft, fast hoisting, and economical operation, skip-hoisting is preferred.

Skips employed at metal mines are usually of the self-dumping type. In capacity they usually range from 8 to 10 or 12 tons, depending upon daily output and number of shifts during which hoisting is done, depth of shaft, etc.

The skips are usually loaded from storage pockets at the side of the shaft, sometimes directly and sometimes from an intermediate measuring hopper holding one skip-load of ore. The measuring hopper serves to speed up hoisting, since it is loaded by the skip tender during the time the skips are in motion. As soon as the skip stops below the hopper, the tender releases the door, and the skip is filled almost instantly. The hopper arrangement insures a full skip-load without overfilling and with minimum spillage into the shaft. It is advantageous from a safety standpoint in that the skip tender has no occasion to go into the shaft, reach out into it, or even to look into the skip to see if it is properly loaded and ready to be hoisted.

At some mines a measuring chute holding one skip-load of ore between an upper and a lower gate serves the same purpose as a measuring hopper. Figures 31, 32, 33 show common types of measuring hoppers and chutes.

Some ore is of a character which will not permit the use of skip-pockets and the ore is dumped directly from the cars into the skip through a short open chute. Some hard ores which break in large blocks will arch and hang up over the chute if dumped into skip pockets. Other ore is wet and sticky and packs in the pockets so that it can not be drawn out quickly but requires barring and poking to get it out of the pocket and into the skip. Some fine sulphide ores, if left

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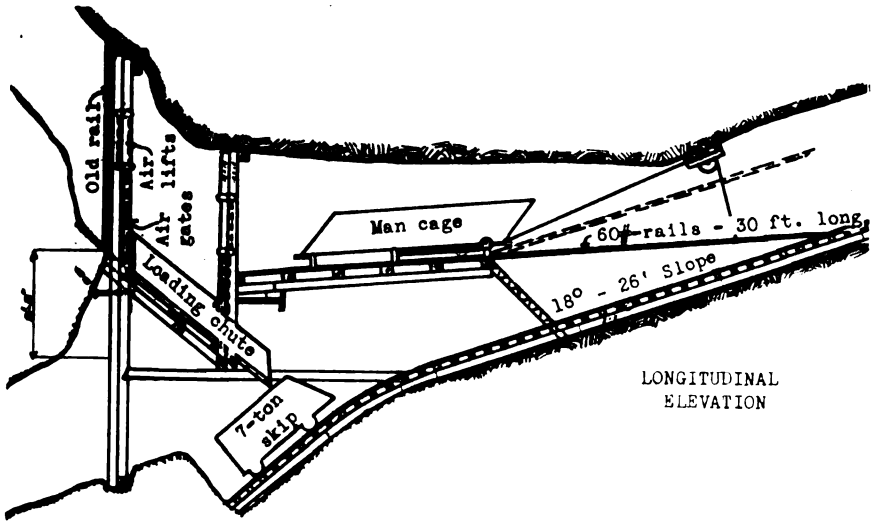

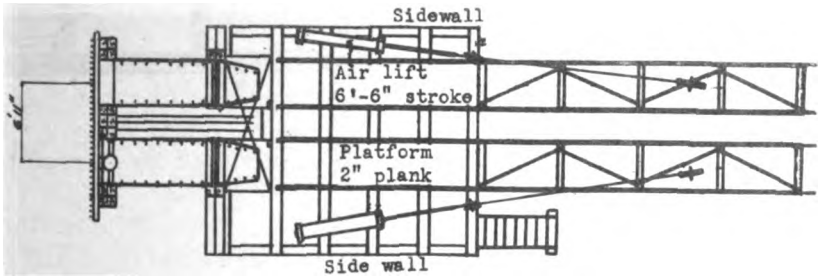

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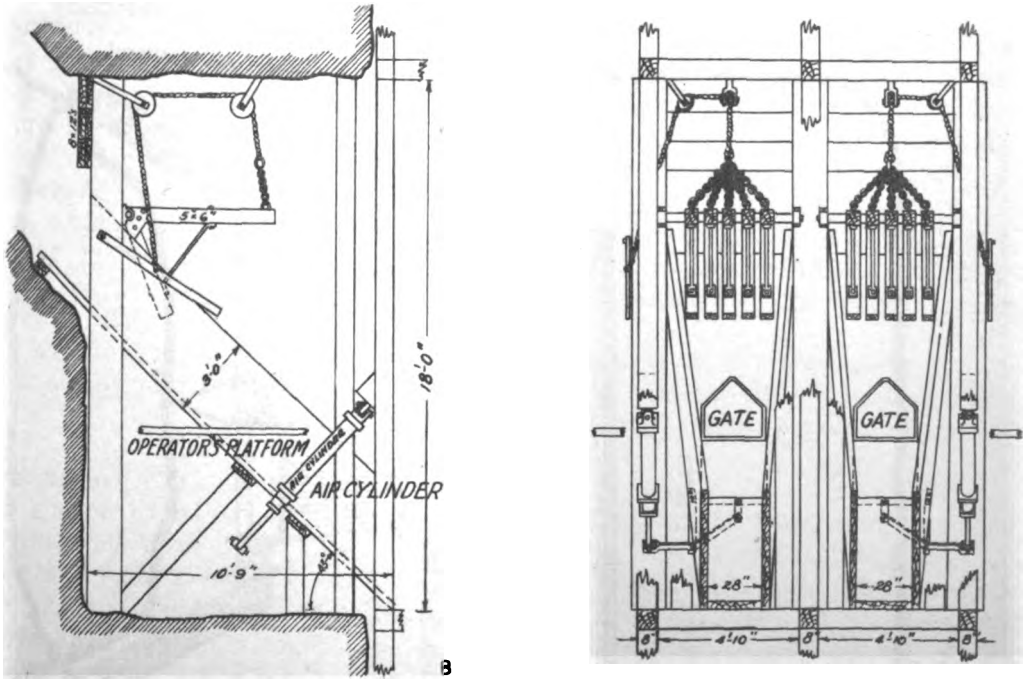

B

Figure 31.- A, Section through front and loading gates, and plan of cage platform and rails; B, skip-loading chutes

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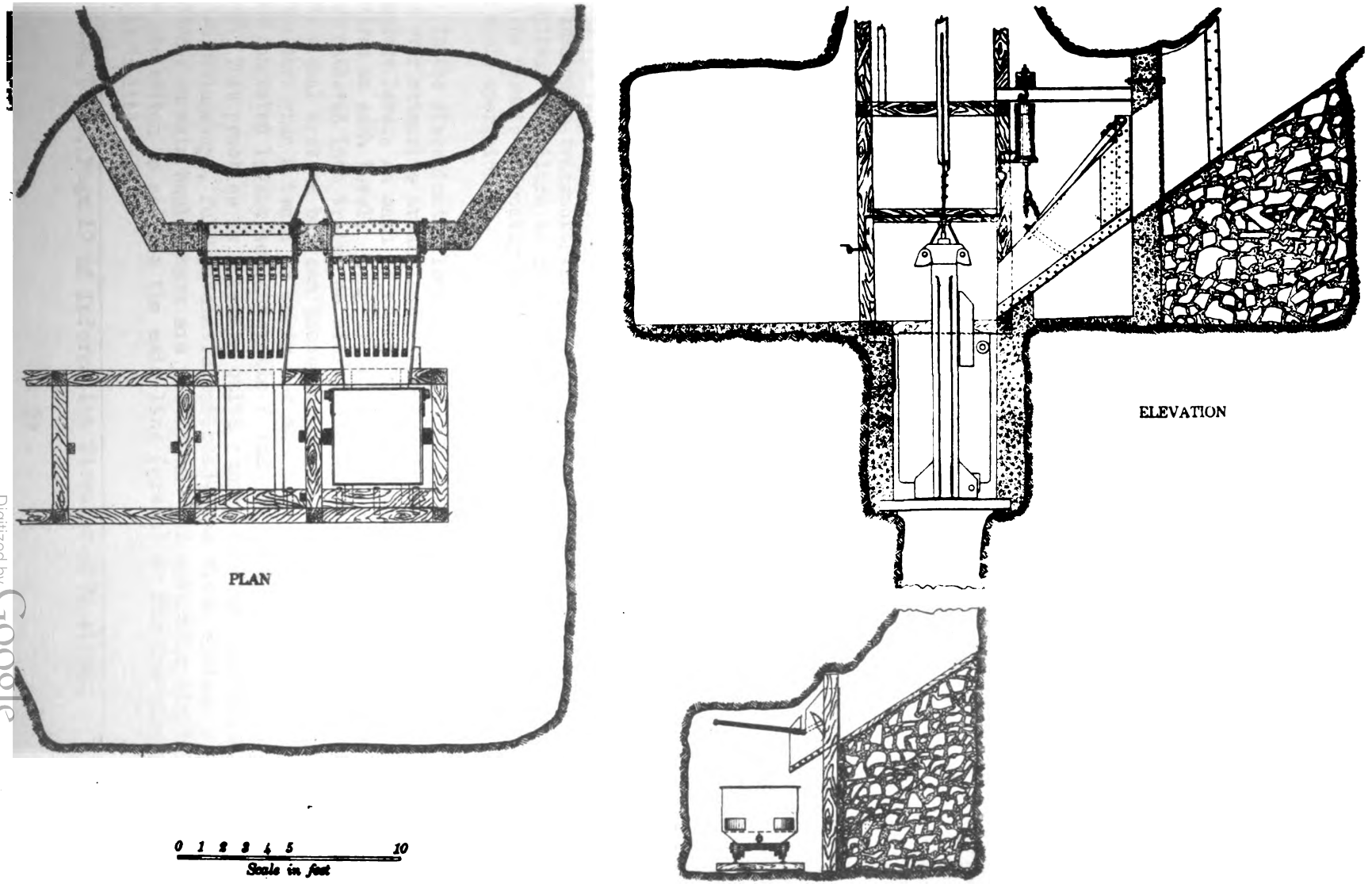

Figure 32.- Skip-loading arrangement, No. 2 mine

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in the pocket for a few hours, will agglomerate into a hard mass through formation of sulphates and can only be removed by picking or sometimes will even require blasting to loosen them up. Under all such conditions hoisting speed can usually be improved by dispensing with skip pockets and loading the skips directly from cars.

It is often necessary to hoist waste either to surface or from one level to another for use as filling material in stopes. When hoisting waste to the surface skips can be used, but it is usually necessary to provide waste as well as ore pockets in the shaft and sometimes to place a waste pocket on surface. When hoisting waste from lower level development to upper levels for filling purposes, cars hoisted on cages are usually employed. Some shafts are provided with two compartments for skip-hoisting with one or two cage compartments in addition.

Sometimes the skip is hung below a cage in the same compartment; the skips are used when hoisting ore, and the cages for handling men, timber, supplies, and cars of waste. Obviously, the skip can not be used for hoisting ore while the hoist is being used for handling men, supplies, or waste, and if the full shaft capacity will be required for ore, a separate shaft or separate compartments should be provided in the same shaft for these other purposes. However, if shaft capacity will not be taxed, this arrangement will save the cost of a hoist and its installation and the labor of extra hoist engineers to operate it.

In Table 5 are summarized some of the data on shafts, skip capacities, methods of loading, etc., at a number of mines which have been described in recently published articles.

COORDINATION OF UNDERGROUND TRANSPORT

In many of the larger mines of the country, transportation is recognized as one of the very important divisions of underground operation and is treated as such. Inadequate transportation facilities for handling ore, waste, materials, and supplies, or failure to coordinate transportation with the other underground operations results in costly delays in the stopes and development faces and slows up the whole operation.

In the disseminated lead district of southeast Missouri, single mines operate over extensive areas, and a number of mines are connected underground on main haulage levels on each of which large tonnages are handled daily by several locomotives on each level. Long trains are hauled at a speed of 15 miles per hour. Cars are gathered into trains on sidings or "loops" as they are locally termed. Electric signal systems between these loops and the shaft are employed to notify the dispatcher when a train is ready for the main line locomotive.[49] On some of the less congested levels semiautomatic (hand-operated) block signal systems are employed. This practice is becoming quite common in other districts. On more congested haulageways, full automatic railroad-type block systems are installed. All switches on main haulageways are protected with automatic lights, which show whether the switch is set for the main line (green) or for the turnout or if the switch is "split" (red).

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[49] Jackson, C. F., Page 17 of Information Circular 6170 cited.

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At the Inspiration Mine[50] safety and speed of train movement are improved by an electric block system similar to that used on steam railroads. Centrally located, electrically operated switch-throwing devices are also installed for the same purposes.

In many of the iron ore mines in the Lake Superior district, block signals are employed on levels where more than one locomotive is in operation.[51]

At the Colorado mine of the Cananea Consolidated Copper Co. telephone signalling is used to obtain the right of way between loading stations in the mine and the ore bins outside at the end of the long main adit.

In some mines where a large amount of waste for filling must be distributed in cars on the various levels, the haulage problem becomes very complex. When cut-and-fill stoping is employed, waste for filling must be supplied in definite quantities when needed; otherwise stope operations are delayed and efficiency impaired. It often becomes necessary to handle waste and ore simultaneously on the same level, and good coordination is required to keep the ore going out and waste coming in without interference. This difficulty becomes greatest where the stopes are so scattered that waste can not be handled through a few main waste passes direct to the stopes.

The handling of steel, timber, explosives, and supplies may interfere with ore haulage unless careful planning is done. In some mines where the active workings are spread over a wide lateral area, centrally located steel racks, tool rooms, powder magazines, and timber yards are arranged to which supplies are brought between shifts. Some mines locate the steel sharpening shop underground to eliminate handling of steel in the shaft as far as possible, and this is especially effective in mines with only one or two levels. Others go further and place the drill repair shop and even the car repair shop underground.

At multiple level mines the more common and better practice is to provide separate cages for handling men, materials, and supplies either in the main shaft or in auxiliary shafts. In very deep mines, the handling of men, materials, and supplies becomes greatly complicated, especially if separate shafts or compartments are not provided for this purpose, due to the time required to make each hoist. In a recent visit to one of the deep mines in Michigan it required seven minutes to hoist the cage from the bottom in bringing the bosses up for lunch and no stops were made at intermediate levels.

Many mines now employ cars and trucks especially designed to transport drill steel, timber, explosives, etc., with a minimum amount of rehandling. Thus drill steel is loaded into special steel cars in the shop, the cars are run on the cage, lowered to the level and then run to the steel supply racks or stope as the case may be. Timber trucks are loaded in the timber yard and run onto a cage long enough to receive the ordinary lengths of mine timber when laid flat. These

50 Stoddard, Alfred C., Mining Practice and Methods at Inspiration Consolidated Copper Co., Inspiration, Arizona. Information Circular 6169, Bureau of Mines, 1929, p. 15.

51 Eaton, Lucien, Page 10 of Information Circular 6179, cited.

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trucks are run off on the level to the timber station or place of use without any rehandling. These special cars and trucks, which are of various designs and construction according to the preferences of the operator, serve a useful purpose in saving labor and in quickly releasing the cage for other work instead of keeping it at the surface or level for considerable periods for loading or unloading materials.

TRANSPORTATION COSTS

As might be expected, underground transportation costs show a wide variation at different mines as a result of the wide variations in conditions. As pointed out at the beginning of this paper, transportation costs constitute an appreciable proportion of total underground costs and therefore deserve careful consideration in connection with efforts toward efficiency in mine operation.

Table 6 gives costs for haulage and hoisting in dollars, man-hours per ton, and kilowatt-hour consumption at a number of mines described in detail in various bureau information circulars. Since the conditions affecting these costs vary so widely and are so complex, no attempt is here made to discuss them in detail, but references are given in the table so that the reader may study them if he desires.

The costs for haulage and hoisting combined per ton of ore hoisted vary at 31 mines from a low of 8.6 cents to a high of $1.226, and they average 33.6 cents for the 31 mines. The high figure is for a very deep mine in Michigan and represents an exceptional condition. It also includes some loading costs which could not be segregated. The next highest cost is 61.6 cents, and haulage and hoisting costs may therefore be said to vary from 9 to 62 cents, depending upon length of tram; length of hoist; tramming method, whether mechanical or hand; whether output is widely scattered or concentrated on a few levels; amount of waste handled; wage rates; management, etc. The figures serve to emphasize the proportion of total underground costs borne by transportation, the variation for 31 mines being from 4.9 per cent to 56.4 per cent and averaging 21.4 per cent.

On the basis of man-hours per ton for haulage and hoisting combined, costs at 29 mines range from 0.125 man-hours per ton to 1.022 man-hours per ton, the average being 0.390 man-hours per ton. These figures represent from 9.5 per cent to 51 per cent and an average of 29.5 per cent of the total man-hours per ton underground. Power costs at 12 mines ranged from 1.2 to 8.9 kilowatt-hours per ton for haulage and hoisting combined, the average being 3.47 kilowatt-hours. These figures represent from 11.5 per cent to 66.4 per cent and an average of 32.1 per cent of the total kilowatt-hours per ton for underground operations.

It thus appears that underground transportation is an important department of the underground operation, deserving of careful study and control in order to secure high efficiency and low costs.

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Table 1. - Car data, hand-tramming

Reference	Type of car	Capacity of car	Size of body	Height above rail	Method of dumping	Diameter of wheels, inches	Type of bearing	Track gage, inches
Information Circular No.:								
6092	Square box, solid on truck	1.5 tons	6'x 2'7" x 1'8"	2' 7"	End	14	Roller	36
6113	End dump	20 cu.ft.	4'x 2' x 2'6"	?	End	?	?	24
6121, 6150, 6174	Cans on low trucks	0.6 to 0.7 tons	32" diam. 30" deep.	4' 0"	Hoisted direct to surface	-	-	18
6145	End dump	20 cu.ft.	-	-	End	-	Roller	-
6159	End dump	1.5 tons	-	-	End	-	Roller	24
6170	Solid body, rigid on trucks	1 ton	-	-	Cradle	-	-	24
6247	End dump	1 ton, [illegible] cu.ft.			End		-	18
6250	End dump	16 cu.ft.	3'7"x 2'4" x 2'2"	3'8"	End	-	Roller	18
6290	End dump	1 ton, 16 cu.ft.	-	-	-	-	-	18
6294	Swing, end dump	22 cu.ft.	-	3'10"	End	12	Roller	18
Teck-Hughes	End dump	1 ton	-	-	-	-	-	-
Bull. 306	End dump and side dump	1.5 to 2.5 tons	-	-	-	-	-	-

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TABLE 2 - Motor haulage, car data

Reference	Type of car	Capacity of car	Body dimensions	Height above rail	Method of dumping	Diam. of wheel, inches	Wheel base, inches	Type of bearing	Type of coupling	Track gage, inches
Information Circular No.:										
6092	Granby	3.5 tons	5'x 8'x 2'6"	4'5"	ramp	13	46	outside journals R.R.type	auto-matic	36
6107	?	6.0 tons	—	—	—	—	—	—	—	—
		8.0 tons	—	—	—	—	—	—	—	—
6113	End dump	20 cu. ft.	4'x 2'6"x2'	—	end	—	—	—	—	24
6138	End dump	2.5 tons	—	—	end	—	—	roller	—	—
"	Rocker	5.5 tons	8'8"x 5'3"x 2'6"	4'8"	side	16	48	roller	auto-matic	30
6145	End dump	20 cu. ft.	—	—	end	—	—	roller	—	—
6149	End dump	7 tons	9'x 5'x 3'9"	—	rope	—	—	roller	—	24
"	Granby	5 tons	—	—	air jack	—	—	roller	—	24
"	Rocker	2 tons	—	—	side	—	—	—		—
"	End dump	4 tons	—	—	end	—	—	—		—
6160	Solid body rigid on trucks	1 ton & 2 tons	—	—	rotary dump	—	—	—	-	24
6167	Solid body	4.6 tons	—	—	rotary dump	—	—	—		30
6168	Gable bottom	2 tons & 6 tons	5'10"x 3'9"	—	side	12	27	—	auto-matic	18
6169	Rocker	2 tons	—	—	side	—	—	crown brass	—	—
"	Solid body	5 tons	—	—	rotary dump	—	—	crown brass	—	—
"	Gable	5 tons	—	—	side	—	—	tapered roller	—	—
6170	Solid body	2.5 tons	6'4"x 4'x 1'9"	3'4"	rotary dump	16	—	R.R.type outside journals	link	24
6179	Rocker	36 cu.ft.	—	—	side	—	—	—	auto-matic	30
"	Gable	65 cu.ft.	—	—	side	—	—	—		—
6180	Rocker	36 cu.ft.	—	—	side	—	—	—	auto-matic	30
6186	Flat bottom box	10 tons	—	—	—	—	—	—	—	30
6232	Hopper bottom	5 tons 7 tons	8'1"x 3'8" 10'2"x 4'1"	4'8"	bottom	14½	2.4-wheel trucks	—	pin	24
6237	Side dump	20 cu.ft.	—	—	side	—	—	—	—	18
6238	Side dump	28 cu.ft.	—	—	side	—	—	—	—	—
6239	Solid box	2 tons	6'6"x 3'6"x 1'9"	3'3½	rotary	16	30	R.R.type outside journals	—	24

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TABLE 2 - Motor haulage, car data Continued

Reference	Type of car	Capacity of car	Body dimensions	Height above rail	Method of dumping	Diam. of wheel, inches	Wheel base, inches	Type of bearing	Type of coupling	Track gage, inches
Information Circular No.:										
6240	Side dump	2.5 tons	—	—	side	—	—	—	—	18
6247	Gable bottom	3.5–4 tons and 7 tons	7'4"x 3'9"	4'11"	side	15	36	outside journals	link & pin automatic	18 36
6250	Rocker	30 cu.ft.	—	—	side	—	—	roller	automatic	—
6260	Round bottom	1 ton	—	—	?	—	—	—	—	18
"	" "	6 tons	—	—	?	—	—	—	—	24
6289	Gable	38 cu.ft.	—	—	side	—	—	roller	automatic	—
"	End dump	16 cu.ft.	—	—	end	—	—	roller	—	—
6290	Gable	3.5 tons	10'x 3'	4'2½"	side	12	—	roller	automatic	18
	solid body	4.5 tons	—	—	rotary dump	12	—	roller	one end swivel	—
Bull. 306	End and side dump	2, 3, 4, & 5 tons	—	—	end and side	—	—	—	—	24,30,36, 40, 48
Bull. 306	Solid body	7 tons	—	—	rotary dump	—	—	—	—	52
Homestake	End dump	20 cu.ft.	—	—	end	—	—	—	—	18
T.A.I.M.E. Vol. 72	Gable bottom	20 cu.ft.	—	—	side	—	—	—	—	18
T.A.I.M.E. Tech.Pub.314.	Gable bottom	3.6 tons	—	—	side	—	—	—	—	24
United Verde Am. Mining Congress Journal, April, 1930.	—	24 cu.ft.	—	—	—	—	—	roller	—	18

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TABLE 3 - Track data

Reference	Type of haulage	Capacity of cars	Weight of locomotive	Weight of rail, lbs.	Ties		Grade of tracks	Curve radius, ft.	Track gage, inches
					Size	Spacing			
Information Circular No.:									
6138	motor	2.5 tons	1½, 4 and	?	—	—	—	—	30
		5.5 tons	6½ tons	40					
6145	Motor	—	"trammer" size	18 & 24	—	—	0.5%	—	18
6149	Motor	2 to 7 tons	1 to 6 tons	40	—	—	—	—	24
6150	Mule	0.6 to 0.7	—	12	3"x 4"	—	—	—	18
"	Hand	tons	—	8	—	—	—	—	—
6159	Mule and hand	1.5 tons	—	20	—	—	—	—	24
6160	Motor	1 and 2 ton	4 tons	30	—	—	4% maximum	—	24
6167	Motor	4.6 tons	8 tons	45 and 35	6"x 8"x 4'6"	—	0.25 to 0.33%	50 to 60	30
6168	Motor	2 to 3.6 tons	3.4 and 4.5 tons	30	6"x 6"x 3'0	—	0.5%	50	18
6169	Motor	2 and 5 tons	8 tons	40 and 60	—	—	—	60 standard 35 minimum	
6170	Motor	2.5 tons	15 tons	30-56	—	—	0.5%	—	24
"	Mule	2.5 tons	—	20	—	—	—	—	—
6179	Motor	2 to 3.5 tons	6.5 tons	40	—	—	—	—	30
6180	Motor	2 tons	6.5 tons	40	—	—	—	—	30
6186	Motor	10 tons	18 tons	50	—	—	—	—	—
6237	Motor	20 cu. ft.	3 & 4 tons	30	—	—	0.5%	40	18
"	Hand	20 cu.ft.		12,24	—	—	—	15	18
6240	Motor	2.5 tons	10 tons	30	4"x 6"x 3'6"	—	0.5%	—	18
"	Hand	0.75 tons	—	12	—	—	—	—	—
6247	Motor	3.5 to 4 tons	1.5 to 4 tons	30	6"x 8"x 4'0"	24	0.5%	35 min.	18
"	Motor	7 tons	10 tons	30	6"x 8"x 6'0"	24	0.5%	60 min.	36
"	Hand	1 ton	—	16	4"x 6"x 4'0"	24	—	—	—
6250	Motor	2 tons	5 tons	30	—	—	—	25 min.	—
"	Hand								
6260	Motor	1 ton	3 tons	20	4"x 8"x 3'0"	—	0.25%	—	18
"	Motor	6 tons	7 tons	30	5"x 8"x 4'0"	—	0.25%	—	24
6290	Motor	3.5 & 4.5 tons	4 tons	40, 45	4"x 6"x 3'0"	30	0.25 to 0.50%	30 min.	18
"	Hand	16 cu. ft.	—	16	—	—	—	—	—
6294	Hand	22 cu.ft.	—	16	—	—	0.5%	—	18
Bull. 306 several mines	Motor	2 to 7 tons	2.5 to 13 tons	20,30,60	—	—	1 to 1.5%	—	24 to 52
Homestake T.A.I.M.E.Vol.72	Motor	20 cu.ft.	3.5 to 5.0 tons	40	—	—	—	—	18
Miami Copper T.A.I.M.E.Tech. Pub.314, 1930.	Motor	3.6 tons	6 tons	45	—	—	0.4%	48'3"	24
United Verde Am. Mining Congress Journal, April, 1930.	Motor	—	—	50	—	—	0.25 to 0.5%	—	18

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TABLE 4 - Locomotive data

Reference	Type of locomotive	Weight tons	Rated draw-bar pull lbs.	Rated speed full load, miles per hour	Motors	Batteries	Cars: Weight empty, pounds	Cars: Capacity, tons	Cars: Number in train	Average haul, feet	Total tons ore per locomotive shift
Information Circular No.:											
6092	Trolley		1,200 & 3,000					3.5			
6107	Trolley			6.0				(6	20)		
								(8	15)	4,000	1,300
6113	Trolley	4.5						1	40		
6138	Trolley	6.5			2 motors 250 volts			5.5	5 or 6		
	Battery	1.75 to 4				Edison A-4 cells		2.5			250
6145	Battery trammer type							1	6 to 8	1,200	100 to 150
6149	Trolley and cable reel	4 to 6						4 to 7			
"	Battery trammer type	1 to 2									
6160	Trolley	4.0			2 motors 250 volts			1 to 2	8 to 14		
6167	Compressed Air	8.0	3,000					4.6	20 to 25	3,000 (main line)	
6168	Trolley	4.0	2,000	5.0	2-20 hp. 135 volts			3.6		2,300	800 to 1,000
"	Trolley	4.0						2	10	1,700	300 to 400
"	Battery	4.5		7.0							
"	Battery	3.0						1	8 to 10		
6169	Trolley	8.0			2 motors			5	10 to 25	6,600	
6170	Trolley	15.0		15.0	2-90 hp. 275 volts			2.5	up to 30	5,000 to 7,000	
6179	Trolley	6.5			2-37½ hp. 250 volts			4			
6180	Trolley	6.5			2-37½ hp. 250 volts			2	10		
6186	Trolley (main line)	18.0						10	44	10,000	
	Battery (advance development)										
6237	Trolley	4.0, 6.0			250 volts			1	35	3,100	

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TABLE 4 - Locomotive data--Continued

Reference	Type of locomotive	Weight tons	Rated draw-bar pull lbs.	Rated speed full load miles per hour	Motors	Batteries	Cars: Weight empty, pounds	Cars: Capacity, tons	Cars: Number in train	Average haul, feet	Total tons ore per locomotive shift
Information Circular No.:											
6238	Battery	4.5				78 cells		1.5	10		
"	Trolley (in tunnel)	6.5			550 volts		4,000	4.2	16	10,000	
6239	Trolley (same with cable reels)	6.0						2			
6240	Battery	10.0						2.5	8 to 10	2,000	
6247	Battery	1.5						1	5 or 6	400	65 to 100
"	Trolley and cable reel	4.0					4,000	3.5 to 4	6 to 10	800	
"	Trolley	10.0			2 motors				12	3,200	1,000
"	Trolley	10.0			2 motors		5,300	3.5	6 to 10	4,200	175 plus timber and supplies
6250	Trolley	5.0						1.5 to 2			
	Battery (trammer used for scattered tonnage and waste)										
6260	Battery	3.0						1	10		240
"	Battery	7.0						6	10		
6289	Trolley	3.0 (main levels)			220 volts			2.5			
	Battery	1.5 (intermediate levels and gathering)									
6290	Double trolley gathering levels	(small)			2 motors				20 with 2 locos. in tandem		
	main tunnel	4.0	2,000		240 volts		3,450	4.5		10,000	
Bull. 306, several mines	Trolley	13.0	6,500					7	5		
	Trolley and battery	2.25 to 3	600 to 1,000	6 to 8		48cell Iron-clad		2 to 5	2,4,6	over 1,000	
T.A.I.M.E. Technical Publication 314.	Trolley	6.0	3,000	6.5	2 motors 250 volts 2 locos. in tandem			3.6	35 (tandem)	5,000	950 to 1,000
United Verde Am. Mining Congress Journal, April, 1930.	24 Battery 9 Trolley (long hauls)	5.0			250 volts	Both lead & alkaline types		24 cu. ft.	16	1,200	225

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TABLE 5 - Hoisting data

Reference	Hoisting shaft data				Method of hoisting ore	Tons ore, 24 hours	Auxiliary shafts	Skip loading method	Remarks
	Shaft inclination degrees	Size	Depth, feet	Hoisting levels					
Information Circular No.:									
6092	Incline 20 - 30°	15x 20'	3,600 on incline	1,000 to 1,500ft. inter-vals	7-ton skips in balance	2,500	yes	From main level pock-ets	Ore hoisted to under-ground pock-ets in in-cline; thence vertical shaft to to surface.
6107	90°	2-5' x 6' 1-5' x 5' comp'ts	973	500 ft.	4.6 ton skips in balance	5,000	For men, supplies & waste	?	
6113	90°	—	270	270 ft.	2.5 ton skips in balance	460	For men and sup-plies	Direct from pocket	Capacity 1,400 tons per 24 hours.
6121	90°	5 x 11'	260	260 ft.	1 400 pound cans	400	For men and sup-plies	Cans hoist-ed to sur-face	
6138	2 shafts 90°	10 x 14' inside	1,060	11 levels	5.5 ton skips in balance	1,400	No.-sep-arate cage comp't	Dump cars directly into skip over slide	
6145	90°	2 skip & 1 manway	—	13 levels	3.5 ton skips in balance	1,200 (2 shifts)	Skips hung un-der cages	Pockets	Most of ore from pockets 800 to 1,500 levels.
6149	70°	6'x 18'6" inside	1,600	13 levels	7 ton skips in balance	1,550	For sup-plies and waste	Pockets or direct from cars to skips	Two classes of ore
6150	90°	5 x 7'	315	2 levels	1,400 pound cans	400	—	Cans hoist-ed to sur-face	
6159	90°	6 x 10' inside	300	1 level	Self-dumping cages in bal-ance	450	For men and sup-plies	—	
6160	90°	6 x 18' inside	586	1 level 560 ft.	Skips in bal-ance	560	No.-skips hung un-der cage	Vertical gate direct from pocket	

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TABLE 5 - Hoisting data--Continued

Reference	Hoisting shaft data				Method of hoisting ore	Tons ore, 24 hours	Auxiliary shafts	Skip loading method	Remarks
	Shaft inclination degrees	Size	Depth, feet	Hoisting levels					
Information Circular No.:									
6167	2 shafts 90°	6' x 14'8" inside	(?)	4 at 150 ft. intervals	10.5 ton skips in balance	9,000 (from 2 shafts)	2-for men waste and supplies	Measuring hoppers	
6168	90°	No.3 shaft, 3 comp'ts. each 4x5'	2,550	3 main levels	3-ton skips in balance	800	3-for men supplies, waste & ventilation	Measuring hoppers	
6169	Twin shafts 90°	5'6"x 19'2"	802	450 and 690 feet	12.5 ton skips in balance	13,300	yes	Measuring hoppers	
6170	90°	6 x 15' inside	275	175 and 245 feet	2.75 ton skips in balance	2 000	For men and supplies	Measuring chutes	
6174	90°	5 x 7'	205	--	1,400 pound cans	450	no	Cans hoisted to surface	
6179	2 shafts 90°	10'10" x 14'10"	No.1 1730 No.2 675	5 levels 4 levels	4 ton skips in balance	1,200	No.3 shaft	Measuring pockets	
6180	90°	11'3" x 10'10" inside	1,250	200,300, 400,950, 1,200	1,-4-ton skip in balance with cage	650	no	Pockets holding one skip load.	
6237	90°	2 skip and 2 cage comp'ts	2,600	200 ft. level interval Average hoist	3.5 ton skips in balance	1,500, ore 400 waste			Hoist 2 shifts
6238	90°	4 comp'ts	2,750	13 levels, 200 ft. intervals	4 ton skips in in balance	800	no	Direct from pockets	Underground shaft
6239	90°	2 skips 1 cage 1 pipe	612	1 at 520 ft.	5 ton skips in balance	2,200	no	Finger gate direct from pocket	
6247 Capote	90°	5 comp'ts 4 x 5'			3.5 ton skips in balance	--	--	Measuring hoppers	
6250	2 shafts 90°	5'6"x 14'6" inside	--	2 main levels	3 ton skips in balance	800	For men and supplies	--	Ore hoisted one shift only

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TABLE 5 - Hoisting data—Continued

Reference	Hoisting shaft data				Method of hoisting ore	Tons ore, 24 hours	Auxiliary shafts	Skip loading method	Remarks
	Shaft inclination degrees	Size	Depth, feet	Hoisting levels					
Information Circular No.:									
6260	90°	6 x 15' inside	No.3,830 ft.	5 levels	2 ton skips in balance	450	For men	Measuring chute	Ore hoisted mostly on night shift, skips for timber and supplies day shift.
6290	90°	5'x 11'6" inside	600		1,-6-ton skip in balance with cage		—	—	
6294	90°	6 x 20' inside	600	350,450, 550 ft.	3-ton skip in balance with cage	200	—	Direct from pocket	
Red Jacket Bull. 306	90°	(14 x 25' (6 comp't	4,900		10-ton skips in balance				
Miami; T.A.I.M.E. Technical Publication 314	90°		811		10.5 ton skips balance	18,000		—	
Teck-Hughes	90°								
	No. 1	5'10"x 10'	580		cage and counter-balance		—	In cars	
	Central	6'4" x 21'4"	3,000	(1,300 (and (1,900	2 2½-ton skips in balance		—		
	South	12'6" x 13'			2 skips in balance		—		Cages with skips hung beneath

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TABLE 6 - Underground transportation costs per ton ore hoisted

Reference	Cost in dollars; labor, power and supplies			Per cent of total underground cost	Man-hours per ton; haulage and hoisting	Per cent of total underground man-hours per ton	Kw.h. per ton hoisted			Per cent of total kw.h. per ton for mining
	Tramming and haulage	Hoisting	Total				Haulage	Hoisting	Total	
Information Circular No.:										
6092[1]	$0.416	$0.211	$0.627	56.4	0.172	18.0	0.756	4.130	4.886	50.3
6113	-	-	-	-	.282	21.0	[2].920	2.770	3.690	37.2
6121	-	-	-	-	.125	14.3		2.420	2.420	42.1
6138[1]	-	-	.217	17.0	.212	18.0	[2].68	1.820	2.500	24.2
6145	-	-	.388	15.2	.640	14.8	(?)	3.00	-	-
6149	-	-	.386	34.0	.205	15.6	-	-	-	-
6150	.064	.091	.155	19.7	.367	35.3	-	-	-	-
6159	-	-	.217	25.2	.305	34.3	(?)	2.79	-	-
6160	.178	.044	.222	26.4	.264	30.2	-	-	-	-
6167	.091	.020	.111	16.4	-	-	-	-	-	-
6168	-	-	.616	12.2	.639	15.0	-	-	8.917	25.8
6169	-	-	.144	24.7	-	-	-	-	-	-
6170	-	-	-	-	.184	22.2	.70	.50	1.200	11.6
6174	-	-	-	-	.366	43.8	.00	2.77	2.770	66.4
6179 (a[1]	-	-	.133	13.8)	-	-	-	-	-	-
(b[1]	-	-	.133	10.9)	.196	21.1	[2].84	2.05	2.890	34.5
6180[1]	-	-	.154	18.5	.158	22.7	-	3.64	-	-
6186	-	None	.114	38.3	.132	49.7	-	-	-	-
6232	-	-	.322	11.2	.381	18.7	-	-	-	-
6237	-	-	-	-	.950	25.5	2.00	13.1hp.	-	-
6238	-	-	.530	12.5	.419	10.0		4.35	-	-
6239	-	-	.278	43.5	.368	44.3	[2].63	1.06	1.690	17.5
6240	-	-	.210	6.7	-	-	-	-	-	-
6247(Colorada	-	-	.166	6.8	.494	13.6	.986	3.373	4.359	38.6
(Capote	-	-	.202	13.6	-	-	-	-	-	-
(Veta Grande	-	-	.108	4.9	-	-	-		-	-

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TABLE 6 - Underground transportation costs per ton ore hoisted--Continued

Reference	Cost in dollars; labor, power and supplies			Per cent of total underground cost	Man-hours per ton; haulage and hoisting	Per cent of total underground man-hours per ton	Kw.h. per ton hoisted			Per ent of total kw.h. per ton for mining
	Tramming and haulage	Hoisting	Total				Haulage	Hoisting	Total	
Information Circular No.:										
6250	.357	.151	.508	14.3	-	-	-	-	-	-
6260	-	-	.438	26.1	.381	24.8	-	-	-	-
6290	-	-	.282	7.1	.330	9.5	-	6.94	-	
6294	-	-	.399	15.3	1.022	34.9	-	1.20	1.200	11.5
Tock-Hughes	-	-	.443	14.4	.616	24.6	-	5.10	5.100	26.1
Bulletin 306										
Mine A	.647	.579	1.226	34.7	[3].854	[3]29.1	-	-	-	-
Mine B	.372	.148	.520	40.2	[3].624	[3]51.1	-	-	-	-
Mine C	.303	.176	.479	30.8	[3].401	[3]36.3	-	-	-	-
Mine D	.393	.201	.594	32.4	[3].390	[3]31.5	-	-	-	-
Mine E	-	-	-	-	[3].820	[3]22.6	-	-	-	-
Miami T.A.I.M.E. Technical Publication No. 314	.053	.033	.086	21.5	-	-	-	-	-	-
Averages	10 mines		31 mines	31 mines	29 mines	29 mines	-	-	12 mines	12 mines
	$0.287	$0.165	$0.336	21.4%	0.390	25.9%			3.468	32.1%

1 - Figures given in circular based on long ton (2,240 pounds) reduced to short ton basis here to conform with data from other mines.

2 - Includes power for lighting.

3 - Data from special communication.

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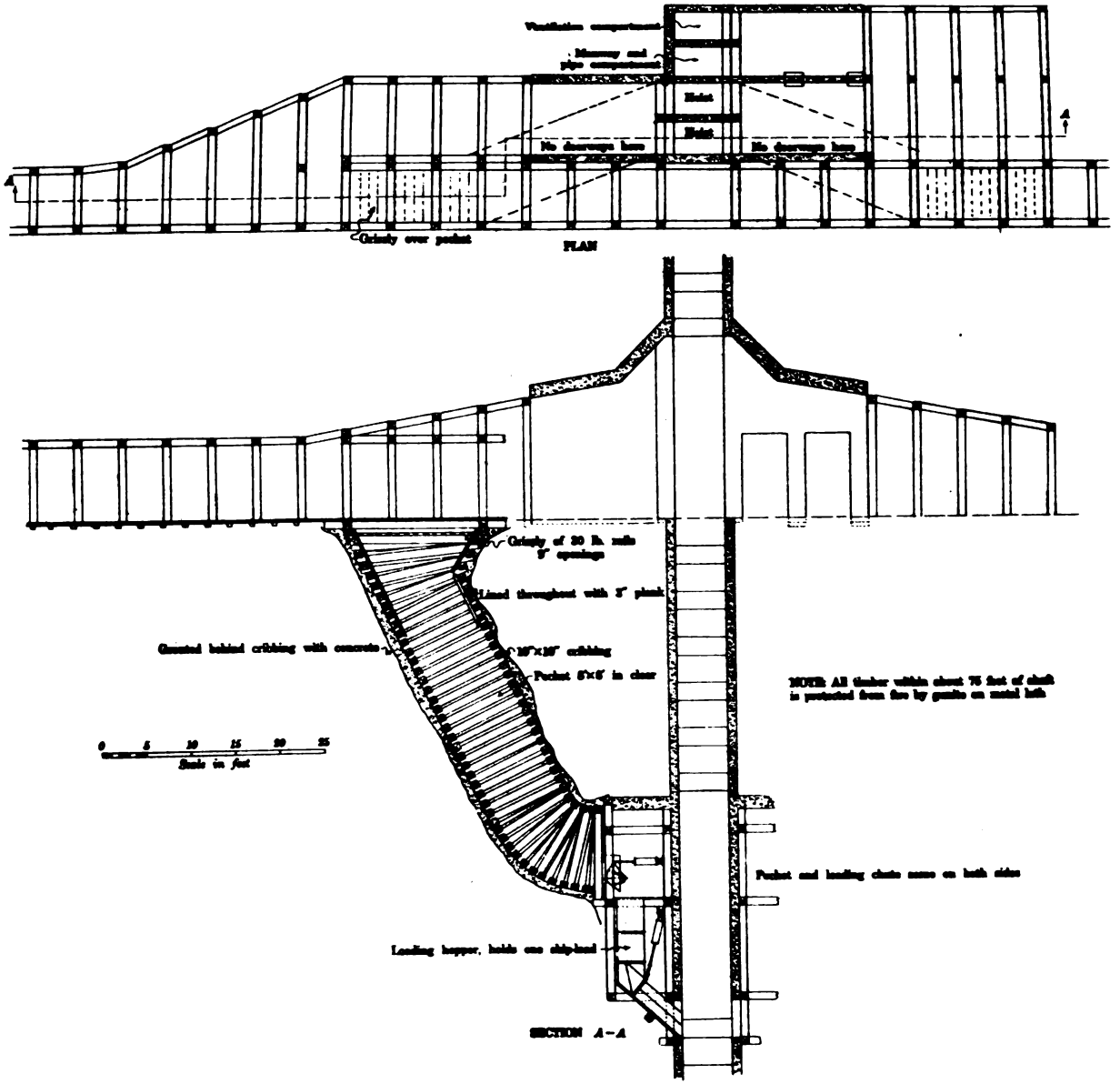
Ventilation compartment
Manway and pipe compartment
Hoist
Hoist
No doorways here
No doorways here
A
A
Grizzly over pocket
PLAN
Grizzly of 30 lb. rails 5" openings
Lined throughout with 3" plank
Cemented bolted cribbing with concrete
36"x36" cribbing
Pocket 8'x6' in clear
NOTE: All timber within about 75 feet of shaft is protected from fire by gunite on metal lath
0 5 10 15 20 25
Scale in feet
Pocket and loading chute same on both sides
Loading hopper, holds one skip-load
SECTION A-A

Figure 33.- Shaft station and loading pocket

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